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OPERATION DEW LINE*

BY

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In the past several months, you have read press releases of the governments of Canada and the United States in which they jointly announced plans for the establishment of a DEW Line radar network across the Arctic, with Western Electric Company as the prime contractor. The word "DEW" stands for "Distant Early Warning." Back of these announcements is the story of the construction of a trial installation of distant early warning stations for development purposes sponsored by the United States Air Force. This is the story about which I propose to talk to you tonight. It is a story of the far North, the Arctic, of pioneering in electronics, transportation, construction and operation, of close military-civilian teamwork, of organization and of action directed at meeting a threat to our national safety.

To go back a little farther, this story really had its beginning in 1949 when the first atomic bomb was exploded by Russia. The start of the Korean War in July 1950 came as a further warning signal to alert America of the possibility of a third World War. New systems of defense were clearly needed in the face of these developments and the Air Force took steps to bring an organized scientific attack on the problem.

As part of this program, Lincoln Laboratory was established with M.I.T. under Air Force contract to study the entire defense problem from a technical standpoint and conduct research and development work on defensive systems. During the summer of 1952, Lincoln Laboratory organized a scientific group to study specifically the problems of early warning. This group has come to be known as the

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"Summer Study Group." Two Bell Laboratories scientists were members of this group. The study concluded that early warning could contribute vitally to the defense of the continent. It is clear that the shortest air route from Russia to the United States and Canada lies over the Arctic.

The Summer Study Group proposed that a DEW line of radar stations be established promptly in the north Arctic to provide four to six hours advance warning of the approach of enemy planes. Such a warning system they reasoned would make it possible to take essential civilian and military defense measures sooner which would greatly improve the effectiveness of our entire defense system. Such an undertaking, however, would require new communication and detection techniques if such a warning system were to be practicable.

Following review of the Summer Study Group's proposal, a decision was made promptly by the United States Air Force to make an experimental trial installation in the Arctic before proceeding with the construction of a full-fledged system.

It was at this point in December 1952 when the Bell System was brought into the project. We were asked to take on the full responsibility for installing a chain of experimental distant early warning stations in the Arctic and to have them functioning within a year. It was proposed that we test new communication and detection techniques suggested by the Summer Study Group, and appraise them under actual Arctic conditions. With such tests, we would obtain first-hand practical knowledge of the DEW line problem not only from the technical standpoint but it would enable us to appraise the tremendous logistic and construction problems and develop techniques for their solution.

In urging acceptance of this most difficult assignment, it was stated by the Air Force that the project was of the highest urgency and importance to the defense of the country and that the Bell System with its integrated development, manufacturing, supply and operating units appeared to be uniquely qualified to assure success of the task.

With this sort of a challenge, there was no hesitation on the part of our top management in accepting the responsibility for this undertaking. The project was assigned to Western Electric Company for its accomplishment. But how the construction and installation jobs in particular could be accomplished in remote stretches of the Arctic in the short interval allowed by the defense time table, was a $64 question at the time the work got under way in mid-December 1952.

An organization had to be built, operating personnel had to be recruited, processed, and trained.

Development work on systems and equipment had to be speeded so engineering work could be completed and the gear manufactured.

Construction designs for buildings and plant had to be worked out.

Vast quantities of equipment, building materials and supplies had to be obtained and delivery made to the Arctic job sites.

Building sites had to be selected and obtained for the experimental installations and, in addition, the job called for surveying a route across the vast stretches of the North Arctic.

These were some of the problems that loomed up large in the minds of those of us assigned to the job of carrying out this undertaking.

Our knowledge of the Arctic for the most part was meager and was based mostly on our recollection of the grammar school geography books we had read many years back. We wondered whether it was really true that there were six months of day and six months of night, whether there was continuous snow and ice which never disappeared as we had pictured in our minds, whether everyone lived in igloos the year 'round as the story books had told us, and whether the only means of transportation would be that of dog sleds. Our first job was to learn as much as we could of the Arctic, in a hurry. Experts were consulted and we soon learned that our impressions of it were quite wrong and our subsequent experience confirmed that the Arctic was not quite as bad as we had pictured it.

A few words on the geography and climate in Arctic Alaska may be of interest.

The Brooks Range—a very rugged mountain range entirely devoid of vegetation, with peaks ranging from 2500 to 10,000 ft.—runs in an east-to-west direction across the northern part of Alaska and the Yukon Territory of Canada just north of the Arctic Circle. This range is about 100 miles across and forms a sort of weather barrier between the true Arctic to the north and Alaska proper to the south.

To the north of the Brooks Range, there is a coastal plain—a narrow strip of land, if you can call it that—ranging from 10 miles to 100 miles in width. In the summer, this coastal plain is scarred by hundreds of rivers and streams which wind their circuitous ways from the Brooks Range to the Beaufort Sea and it is dotted by thousands of fresh water lakes. There are usually long narrow north-south lakes, which probably were part of a river or stream in time past. This coastal plain is covered by tundra, a moss-like type of vegetation which is green and rather beautiful during the summer months. Numerous small wild flowers—white, yellow and pink—grow in profusion. The tundra provides food for caribou and reindeer which abound in this area. In the winter, this plain is a desolate, flat, white, snow and ice-covered stretch with little to distinguish between frozen land and frozen sea.

Total precipitation north of the Brooks Range amounts to 5 or 6 inches per year. Most of this is in the form of rain during the summer months. The snowfall in winter on the level is only a few inches but the snow is constantly on the move and piles up in very high drifts at any point where there is an obstruction. The mean daily temperature during the three winter months is about $-22°$ Fahrenheit, with extreme minima of about $-50°$. The mean daily temperature during the three

summer months is about plus 35°, with maximum temperatures of about 60°. For about two months in the winter, the sun does not rise and similarly for about two months in the summer the sun does not set.

Most of the coastal plain owes its very existence to the fine temperature balance between winter and summer. For the most part, this coastal plain appears to consist of a thin layer of tundra and soil a foot or two in depth covering a gigantic layer of ice. Summer heat thaws the active top layer of tundra and soil, but because of the short duration of summer heat, this insulating frosting on the ice cake prevents the thawing of the sub-surface ice and the flowing away of the coastal plain.

To insure success of the project, with the critical time schedules and the unusual engineering, construction, logistic and operational problems, a special composite Bell System group was established in Western Electric Company which combined many of the normal functions of Western, the Long Lines Department of American Telephone and Telegraph Company and the Bell operating companies. Experienced personnel to carry on these many specialized functions were recruited throughout the Bell System Companies. A similar composite group was set up in Bell Laboratories for coordinating laboratory effort on the experimental installations and for handling specific engineering work.

Since the contract called for operation, maintenance and testing of the facilities by us after construction, it was necessary to recruit an operating force also. Because of the technical nature of the facilities and the isolation of the Arctic stations, specially qualified operating personnel were essential. Direct contact was made with all of the Bell Telephone operating companies by our recruiting representatives and some thousand possible candidates were suggested by the companies for possible Arctic assignments. From this large number, the recruiters selected a small group of men who met the rigid technical requirements for the job. After thorough medical and psychological tests designed to weed out further those who might not be able to stand the physical and mental rigors of the Arctic, those remaining were given indoctrination and training courses designed to bring them to a high state of technical proficiency.

It was realized at the outset that the procurement of equipment, materials and supplies was going to be a very tough problem with the success of the job largely dependent on having the needed materials in time to meet transportation and construction schedules. A group of expert buyers and expeditors from various locations in Western Electric were brought together in the project group to do this job. As rapidly as buyers made contracts with suppliers, expeditors took over, assisting suppliers whenever necessary in obtaining component materials and supplies. In some cases, this assistance went down to third and fourth tier vendors.

An assembly and storage area for equipment and supplies was set up on the west coast. At this location, all shipments were checked in, assembled, properly marked, inspected, export packed and palletized for loading. An early spring deadline was established for material to be transported by air to the Arctic sites and an early summer deadline was established as a readiness date for all material which would follow by ship. These were extremely short intervals considering the fact that a large amount of engineering work was necessary before orders could be placed. Notwithstanding this, the shipping deadline dates were met.

To give you an idea of some of the procurement problems, I should like to cite a few examples. The buildings were constructed from prefabricated panels made by a firm in Connecticut. Many carloads of these panels were needed. Western helped the manufacturer, with his full cooperation, to meet the deadline dates. The orders for delivery of the component materials, such as plywood from West Coast manufacturers and fibre glass from Kansas City, were followed by Western Electric expeditors from suppliers through final manufacture and delivery of completed panels. Delivery schedules were met.

Another example was special electronic equipment. From initial study, manufacture and delivery of this material to meet the deadline schedules appeared impossible. However, with the manufacturer's full cooperation, Western Electric expeditors placed in the factory succeeded in obtaining raw materials and components in time so the manufacturer could meet delivery dates. This involved about 700 separate purchases aggregating 37 tons of material.

Another outstanding example of wholehearted industry cooperation involved tractors. A number were needed on the job. These required special Arctic equipment. Normal delivery would have been almost two years, but delivery was completed in about 6 weeks after the initial order was placed. This was a remarkable achievement.

These examples are typical of industry generally in stepping up to the defense problem and meeting impossible delivery dates. Equipment and material valued in the millions were obtained from some 600 suppliers, large and small. In addition, several million dollars worth of Government material was obtained. Of the materials used, only a small portion was made by Western and its subsidiaries.

Arrangements were made in the early stages of the project for the Navy to haul the freight to the coastal sites in the Arctic. It became apparent soon, however, as we got well into scheduling the project and had progressed a little beyond the neophyte stage in our knowledge of the Arctic, that we could not depend on summer freight delivery in the Arctic for the entire cargo if the job was to be finished on schedule. There just wouldn't be enough construction weather left. Construction camps had to be set up in advance; tractors and machinery had to be

gotten to the job sites and work started. Such machinery could be moved overland only when the surface was still frozen solid—perhaps, if we were lucky, up to May 15—but any time beyond May 1 was a gamble.

Early in the project, several of us made an initial trip to the Arctic to get a first-hand picture of the problem, an idea of how the job might be done, if indeed it could be done at all, and decide generally where the installations would be made. This trip was fruitful. We found that the area we proposed to build in was quite different from what we had imagined. People other than Arctic explorers and Eskimos had been there before. The Air Force had built a base in an area not too far from one of the proposed test locations. True, it was a small one of about 30-man capacity, but there was an air strip which could be used for an air lift operation if it could be cleared of snow. There was an Eskimo village of 8 to 10 families from which guides could be obtained to help us find our way along the Arctic wastes. The Coast and Geodetic Survey parties had headquartered there for several seasons past and had left a camp which could easily accommodate twenty-five to thirty men and could be expanded beyond that. Their larder was well supplied with provisions left over from the past season's work. Their work, however, had been completed and they had no further need for the camp and most of its equipment and supplies. This property was promptly acquired for the project. This was an important windfall. We could now move in with a cook and open camp. Another acquisition was a grounded LST, abandoned some years before, which we soon turned into a heavy duty maintenance shop where tractors, vehicles and other machinery could be repaired without interference from the weather.

A decision was then made to airlift a thousand or more tons of equipment and building material so construction work could get under way. On Friday, March 6, 1953, another lucky break occurred. An account appeared in the *New York World Telegram* to the effect that the Navy was discontinuing oil exploration work in Alaska. This work, we knew, was being handled for the Navy by Arctic Contractors whose offices were in Fairbanks and Point Barrow, Alaska. Our first thought was of securing any of their resources which might now be surplus for use on the DEW Line project. After hurried telephone consultation with the Air Force and Navy over a weekend, a conference was arranged in Washington with the interested Government departments on Monday, March 9, and on March 11, 1953 blanket authority was granted to transfer available material, equipment and supplies from Arctic Contractors to our account for use on the experimental DEW Line project. Another hurried trip was made to the Arctic. On Sunday, March 15, after a day and night flight from New York, our representatives had a 6:30 a.m. conference in Fairbanks with Arctic Contractors

and from there flew directly to Point Barrow for a conference later in the morning with their Field Manager. By noon that Sunday, detailed manifest lists were being made out and the loading of material started for cat-training to our sites. Some 1200 tons of equipment, tools, materials and supplies were obtained, including a number of D-8 tractors, heavy-duty cranes, tons of heavy timbers and piling, power and radio equipment; but, more important, there were 60 equipped Wannigans—enough to permit setting up Field Camps at all construction sites. A "Wannigan" is a building on sleds, about 12 × 20 feet in size. These were completely equipped for camp operations and were of various types—Cook, Mess, Bunk, Power Plant, Water, Shop, Storage, Utility, Steam Point, Office Wannigans, etc.

Time was of the essence because overland haul by cat train would be out of the question after the spring break-up about May 15.

Within less than 24 hours, some of the sleds for the first cat trains which were to haul material to the construction sites were being loaded. On March 18, the first cat train was underway to one of the sites across the Arctic wasteland from Point Barrow with a full load of freight. As a matter of interest, a train consists of seven tractors. The lead tractor is equipped with a scraper blade for breaking trail. The next five cats haul pay load—three or four sleds or wannigans each—and the trail cat hauls the mess and bunk wannigan for the train crew, POL for use enroute and Shop Wannigan for repairs. The first train completed its trip with 300 tons of cargo from Point Barrow to Barter Island, a distance of 410 miles, on March 26, 1953—just 20 days after the account appeared in the New York newspaper. Several more trips were made. A substantial tonnage of cargo was moved by tractor train within the time-table set by nature.

This important break in events changed the entire complexion of the job. Camps could now be opened without preliminary construction effort because of the wannigans obtained, and productive construction work started.

While this was going on, the airlift got under way also. C-124 aircraft —the Globemaster—were used to move heavy machinery, including D-8 tractors weighing over 40 thousand pounds, large cranes, ten cubic yard earth moving machinery, motor vehicles, etc. Other aircraft such as the flying box-car, the C-119, were used to haul tools, building materials, construction huts, food and thousands of other items.

Many hundreds of tons of freight were airlifted. This was a substantial undertaking but worked smoothly. The Air Force cooperation could not have been better.

The main transportation was accomplished by Navy convoy which left from West Coast ports.

Tonnagewise the heavy part of the Arctic cargo was Diesel oil. Vast quantities were required to operate the construction machinery

and later to operate the Diesel generator plants and heat the buildings. Some 26 thousand drums of oil—8000 tons—were shipped. The drums covered almost 4 acres as they awaited shipment, arranged neatly, at the port where they were loaded. If laid end to end, they would stretch for 15 miles or more. The provision of Diesel oil to Arctic installations is one of the major items of expense because of the tremendous transportation problem.

The convoy consisted of a number of ships with Navy and Army personnel aboard to deliver and unload the cargo. The convoy included LST's, AKA's, and miscellaneous craft including ice breakers.

The convoy encountered severe ice in a number of locations in the Arctic. Ice breakers assisted in getting the cargo through, in fact a week or more ahead of any previous Naval expedition into these waters. At times, the going was reasonably good but floating ice was usually near about.

Extremely heavy ice was encountered in the vicinity of one of the sites, and it was necessary to wait for several days before proceeding.

The Commodore, Captain Morgan, an able and conscientious Naval officer, told us afterward that his Ice Reconnaissance Officer and his ships' Captains had advised him against going the entire distance with the ice conditions as they were. The Commodore, however, was not one to give up easily. He said, "Well, we'll give it one more try" and he made it after a long, hard struggle. He reminded me of the story of the spider who tried seven times. The ships got the cargo in and got out safely.

The cargo was hauled directly to the beaches at all sites by LST's or LCU's.

Most of the cargo was brought ashore with LVT's. This is an amphibious vehicle that swims ashore, climbs up on the beach with its tracks and then operates overland much as a tractor. Cargo was temporarily stored on the beach in accordance with a prearranged plan.

The local Eskimo children and their elders were interested observers of the entire unloading operation.

The nature of the Arctic poses many new and unusual problems. There is the problem of construction on the permafrost. Heat leakage from buildings must not be allowed to penetrate the surface and destroy nature's fine balance of temperature or the earth beneath may settle badly or disappear. To prevent this, an insulating gravel pad 5 to 6 feet thick was placed on top of the tundra when it was in its frozen state to provide a stable foundation for the buildings. The building foundations are placed on the gravel pad. In addition, the heated buildings were constructed on cribbing about 5 feet above the gravel pads to reduce possible heat seepage to the permafrost. The gravel pads also serve to keep the building area high and dry during the summer season as it would otherwise turn into a swampy bog

and quickly erode once the surface was disturbed by tracked vehicles. Most of the gravel was moved in the winter months.

The technique developed for digging holes for 80- and 90-ft. antenna poles was also new and unusual. The holes were dug, or melted, in the permafrost during the spring and summer months by means of steam points. The first foot or two usually consisted of tundra and soil, and the next four feet or more was usually solid blue ice. Generally, gravel was encountered near the bottom of the hole. A form consisting of two expanded oil drums welded end to end was inserted in the hole to prevent the hole from caving in before pole setting could be started. When the poles were set and tamped in, they froze up solid and should stand indefinitely.

Another innovation was the use of oil drums to support coaxial cables between the rhombic antenna fields and the receiver building. Empty oil drums are a surplus commodity in the Arctic. The oil drum line was made by placing the drums on their sides approximately four feet apart. The four coaxial cables were placed on top of this pontoon-like structure and lashed together. This arrangement saved many thousands of dollars in construction effort over ordinary pole line construction.

There is also the problem of minimizing fuel consumption and keeping construction effort to a minimum because of the short construction season. To meet these problems, the heated buildings were constructed of insulated panels such as used at other Arctic installations. The panel is prefabricated of plywood preinsulated with 4 inches of glass wool. The outer and inner surfaces are metal covered.

Some of the stations consisted of a number of buildings. These buildings provide quarters for the personnel, housing for the technical equipment and power plants and storage room. Garage and storage buildings are also provided. Some of the stations which are presently unattended consist of a single building. During the past winter, much experience has been gained under actual Arctic conditions with high winds up to 100 miles per hour, low temperatures down to 50 below zero and heavy icing conditions. Much has been learned in Arctic construction which will be applied in the future. For one thing, the present building configuration with its cross corridors invites problems of drifting snow. In future construction, the building facilities will be aligned in one long continuous row, streamlined to minimize snow drifting. Also, ways have been found to extract the heat from the jacket water and exhaust of the Diesel engines to care for the normal building heating requirements. This will reduce the Diesel oil requirements by approximately one third. Likewise, new techniques have been developed in panel fabrication which will materially simplify Arctic construction problems, and reduce materially the number of construction people required at the construction sites and also minimize the construction of temporary camp facilities.

One of the most difficult phases of operating in the Arctic is transportation. Overland travel is possible in winter with track vehicles over a good part of the Arctic but this is slow and during the summer months has been impossible in the past. A new vehicle we call the Sea Wolf has been developed which we hope will help to solve this problem. This vehicle is amphibious and has been quite successful so far. The main dependence for transportation is on Bush planes. These are ski-equipped in winter and use either wheels or pontoons in summer. Gravel air strips were provided during construction at all sites to accommodate wheeled aircraft. Weather presents a difficult problem in flying. Heavy fogs are prevalent and periods as long as ten days are experienced when flying is difficult or impossible. In winter, blowing snow produces a like effect in obscuring the ground.

The construction phase of the DEW line trial installations was completed in the fall of 1953 ahead of the schedule hoped for by the United States Air Force. Since then, the development and test of electronic equipment have been proceeding at a very rapid rate. Many new ideas have been evolved and tried. Unlike ordinary radar, which requires the constant attention of human observers, the new equipment automatically sounds an alarm whenever aircraft approach, reducing drastically the personnel required for service in the Arctic. Moreover, both the radar and radio transmitters which link it with the command centers are proof against the magnetic storms which knock out conventional electronic equipment in the Arctic during substantial portions of the year.

It was because of the success of this trial installation that the United States and Canadian governments decided to proceed with the implementation of a full-fledged DEW system across the Arctic which may serve as a modern electronic Paul Revere to warn America of impending danger in the event of attack upon us.

Operation DEW Line has been a noteworthy example of military-civilian cooperative enterprise supplementing and supporting each other to the end that maximum use was made of the unique experience, skills, and facilities of each in an urgent common endeavor. Success in the construction phase of the DEW Line project could probably not have been achieved in the 1953 season had it not been for the wholehearted support and cooperation by the Defense Department through the Air Force, Navy and Army in all phases of the job, as well as the support of other departments of the United States and Canadian Governments.

A NEW LABORATORY TECHNIQUE FOR INVESTIGATION OF THE ORIGIN OF FLUID TURBULENCE

BY

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ABSTRACT

This paper describes a laboratory technique which provides a new approach to the still unsolved problem of fluid turbulence. The effectiveness of the technique is illustrated by experiments on smooth laminar flow in the boundary layer of a flat plate moving edgewise through still water. The phenomena of breakdown of the laminar flow are explored in search of evidence which may account for the onset of turbulence. Cases are cited in which breakdown of the laminar flow appears to be, not a chaotic upheaval, but an orderly process which may be evaluated. Photographs are included showing boundary-layer phenomena heretofore unknown. The subject matter concerns chiefly the aerodynamics of the airplane, but also applies to the general field of fluid mechanics.

INTRODUCTION—THE TURBULENCE PROBLEM

In aerodynamics, turbulence is a very troublesome element. It increases frictional drag of an airplane, affecting speed and control increasingly as flight speeds become great. Our knowledge of turbulence is incomplete and is limited to a few general facts. We know that it originates always from the breakdown of smooth "laminar" flow. On an airplane wing in flight such a breakdown occurs. The thin frictional boundary layer of the air dragged along by the wing is, at the front, smooth and laminar; but somewhere to the rear it breaks down and undergoes transition to the turbulent form of flow, which then continues for the rest of its course.

The forward laminar part of the boundary layer is well enough understood; we know it consists of streamlines of unequal speeds, slower and slower the nearer the wing surface, until, at the surface, the streamline has zero speed. It exerts a moderate frictional drag on the front part of the wing. On the other hand, the rear turbulent part of the boundary layer is not well understood. We know chiefly that it exerts a more intense frictional drag along the rear of the wing than does the laminar flow along the front; so that the further back the transition point, the less is the total frictional drag. And we know that the location of the transition point depends on the speed, smoothness, temperature, shape, etc. of the wing.

But we do not know what are the fundamental fluid processes which produce turbulence; we do not know what happens in the phenomena of transition and turbulence. These things we should know. Therefore, the writer has sought out a method of research capable of revealing

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these processes. In the following sections such a method will be described and its success will be illustrated by photographs of phenomena heretofore unknown.

METHOD OF EXPERIMENTATION

The problem has been approached empirically rather than theoretically. The objectives have been: to reproduce in the laboratory a typical laminar boundary layer in its simplest form under controlled conditions; to cause the flow in the laminar layer to change, at a certain transition point along its path, from laminar to turbulent; to make visible the transition phenomena which, of course, represent the birth of turbulence; and to measure these phenomena in terms of factual data.

A technique for meeting these objectives has taken form after extended experiments both in wind tunnels and water-flow apparatus. The method adopted has departed from the conventional wind-tunnel method of approach; instead of air as a medium, water has been selected as affording more effective means to study the particular phenomena of boundary-layer transition. Water is a valid as well as a convenient medium for determining the equivalent behavior of air on aircraft. The advantages of water over air are, first, that it requires only about 1/15th as great velocity as air for production of a given phenomenon, because its coefficient of kinematic viscosity is about 1/15th as great; and second, water-flow phenomena visualized by suitable dye tracers are more photogenic than air visualized by smoke.

The outstanding feature of this technique is adoption of a photo-recorder—an instrument used in flight testing of aircraft—to register the phenomena visualized in the water. By its means the time and space characteristics of the visualized flow phenomena are recorded permanently on photographic film so that subsequent micrometer analysis of the film can furnish accurate quantitative data. Water with dye is of itself an old device employed in 1883 by Osborne Reynolds, and later by others, chiefly for qualitative observations. With the addition of the photo-recorder, the earlier qualitative method becomes vitalized and the new technique in its totality provides an effective new tool for quantitative measurements of boundary-layer phenomena. As will be shown, it has been able to reveal and analyze new data on boundary-layer behavior; and it promises to open the way for further and broader researches.

APPARATUS

The apparatus used in the above-mentioned test technique comprises a tank of length four times its width, open at the top, and containing water (Fig. 1). An overhead carriage, electrically propelled, rolls along above the length of the tank, like a marine testing tank in miniature.

The carriage is lightweight and is equipped with a motor giving quick acceleration. For deceleration a cord trails behind the carriage and passes over a series of pulleys to support a known weight. The weight provides a decelerating force at any desired moment when the electric power is cut off, to retard or stop the carriage. From the carriage a strut projects downward to support a plate submerged horizontally in the water below. When the carriage moves along the tank, the plate moves with it; the purpose of the plate is, by its motion through still water, to create on its surface a frictional boundary layer suitable for laboratory analysis.

FIG. 1. Small towing basin for boundary-layer tests.
Over-all size of water tank and wooden supporting framework, 28 × 58 × 105 in.

To make this boundary layer visible for study, dark dye is introduced into the boundary layer by a small tube leading from a dye tank. As the plate is painted white, the dye formations within the boundary layer show up by color contrast against the white background. The latter is illuminated in manner suitable for photography by electric lamps attached to the carriage and therefore moving with the plate.

To record the dye formations against the white background, a motion picture photo-recorder camera is mounted on the carriage,

travelling with it and with the plate. It is pointed downward to photograph in plan view all phenomena visualized by the dye, and to provide on the film, in successive timed exposures, a continuous record of dye motions relative to the plate. The dimensions of the phenomena are recorded in terms of scale graduations marked on the plate and appearing on the plan view films as a background film-grid. The distance travelled by the plate is recorded by reference to a fixed scale

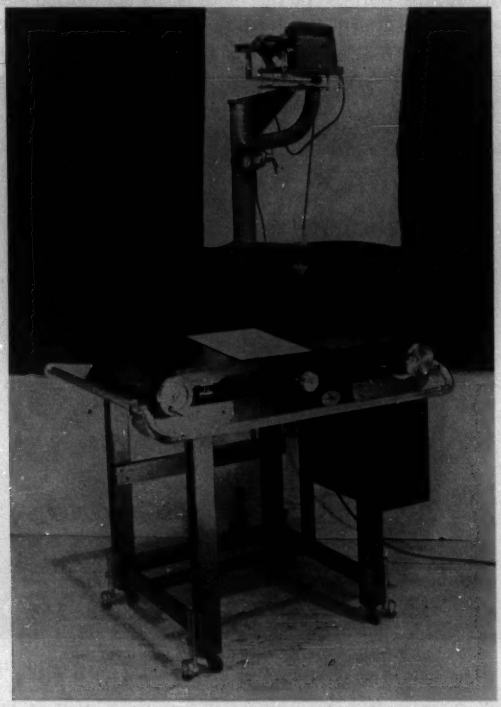


FIG. 2. Projector analyzer for micrometer measurement of photo-recorder film.

mounted under water alongside the path of the plate. For timing these motions, the exposure frequency of the camera is calibrated, or when necessary, established by an electrically operated intervalometer.

After exposure and development the film record is taken into the dark room and converted into tabulated data with the aid of a special projector-analyzer (Fig. 2). This comprises a conventional still projector lantern equipped for 16-mm. film and mounted well above a

horizontal drafting table. The film image is deflected downward to the drafting table from the projector by a 45° mirror. Overlying the drafting table is a screen on which is marked a grid of dimension lines properly scaled. The screen can be shifted in its own plane. In use the screen grid lines are made to match the images of the film grid lines by lateral adjustment of the screen and vertical adjustment of the projector lantern until the grid lines of the screen and those of the film image coincide. A manually operated hand wheel is provided to advance or reverse the film so that each frame can be projected in sequence, one at a time, onto the screen of the drafting table. The image, magnified 21 times, affords a convenient and accurate form of micrometer measurement. In use the dimensions are read off from each frame, one at a time, by the operator, and tabulated against time intervals.

From such measurements the data of this report have been derived. The precisions attainable are as follows: Time, ½%; Distance, 1%; Frequency, 1½%; and Velocity, 1½%.

It is seen that the photo-recorder method of registering visible dye formations in the water provides a permanent record from which can be measured the velocity, frequency, acceleration, duration, direction of motion, rotation, size, and intensity of any phenomena appearing in the camera field of view. In addition to providing these data, the method has the merit that it can record events whose duration is too short to be caught by the naked eye; such events can then be analyzed at leisure on the screen in the dark room.

THREE EXPERIMENTS ILLUSTRATING USE OF THE METHOD

To illustrate the use of the above technique, three experiments will now be presented: first, boundary-layer transition generated by a trip; second, columnar vortices in the boundary layer of a flat plate generated by deceleration of the plate; and third, boundary-layer formations on a rotating disc.

First Experiment

Visualization and Measurement of Transition Generated by a Trip

The first example is a transition test in which the photo-recorder is used to analyze transition caused by a trip. A "trip" is a device used in turbulence studies to interrupt the smooth flow of fluid on a surface and to stimulate the onset of turbulence behind the trip. It takes the form of a fine wire or a sand strip cemented to the test surface spanwise of the flow direction. In using a trip for stimulation of turbulence in boundary-layer studies, the assumption is that the turbulence thus artificially generated has, at a sufficient distance behind the trip, the same characteristics as though produced by natural causes. The trip

has the advantage to the experimenter that it brings transition under his control, and that it permits relatively low speeds to be used.

The functioning of a trip, with its significance in the onset of turbulence, was therefore an appropriate subject for experimentation.

Apparatus for Producing Turbulence by a Trip

For the test a flat dural plate was attached in horizontal position to the bottom of the carriage strut for edgewise motion under water in the tank. The plate was rectangular, 12 in. in span and 18 in. chord, and 0.09 in. thick. The leading edge was faired, but the trailing edge was not. The surface of the plate was painted white, and was marked with a checkerboard of dimension lines.

A strip of tape 0.024 in. thick and 0.5 in. wide was cemented to the plate spanwise at mid-chord, to serve as a trip. Without the trip, the boundary layer would remain laminar over the entire plate due to the low sub-critical speed of the plate. But with the trip, the laminar flow ahead of the trip would be changed to turbulent flow behind the trip.

Operation of Test

In use, the camera and dye were put into operation; the carriage motor was started and the plate reached uniform speed after a starting run of about 6-in. length. The motion of the plate generated a boundary layer over the plate surface; formations within the boundary layer were made visible by the dye and photographed continuously by the camera. Various tests were run at speeds up to 2.5 ft./sec.

Photograph of Transition

Figure 3 shows by two views, a plan and an end view, what happens due to a trip in the path of a boundary layer. The top photograph is a plan view, enlarged from a typical frame of photo-recorder film 30-9 made at plate speed 1.22 fps. This test is the basis of the discussion to follow. In the lower part of Fig. 3 is a series of six end-view photographs enlarged from test film 41-16; these show the cross-sectional shape of dye formations at plate speed 0.64 fps. To obtain such end views a 46° mirror is submerged in the water as will be described later.

Referring to the top photograph of Fig. 3, it is seen that ahead of the trip the flow in the boundary layer is smooth and laminar; this is manifest by the dark layer of dye uniformly distributed over the plate surface and clinging to it and obscuring the white-painted plate surface.

This boundary layer undergoes a violent change on reaching the trip; after passing the trip, the uniform dye distribution is converted into dark dye formations which extend spanwise and alternate with white clear spaces devoid of dye. The dark formations generated at the trip

are seen in full length by the camera; it is to be remembered that the camera, pointed vertically downward from above, records on its film a plan view of the flat plate and the boundary-layer formations overlying it.

The spacing or pitch of the dye formations increases as they drift downstream behind the trip; and they change their form, and their speed increases as will be discussed below.

Behind the trip the flow is no longer laminar. This is shown by the absence of any smooth layer of dye clinging to this part of the surface. Confirmation of the non-laminar nature of the boundary layer behind the trip has been had in other tests, where dye introduced behind the trip cannot be made to cling to the surface in the manner of laminar flow.

Life History of Artificially Tripped Transition Formations

The importance of this experiment lies in the fact that, by means of the photo-recorder technique, the transition phenomena mentioned above can be made visible and can be made subject to evaluation. The film record represented by the plan view enlargement at the top of Fig. 3 has been examined in the projector-analyzer; and from micrometer measurements of successive frames the boundary-layer characteristics have been tabulated as follows:

Velocity of plate through the water	1.22 fps.
Impulse frequency relative to the plate	$8.9\binom{+2.4}{-0.7}$ cps.
Ave. drift velocity of formations behind trip (increasing from 0.24 fps. at the trip to 0.68 fps. at distance 3.9 in. behind trip)	0.52 fps.
Ave. longitudinal pitch distance between formations (increasing from 0.38 in. at distance 0.5 in. behind trip to 1.6 in. at distance 3.8 in.)	0.84 in.
Ave. lateral pitch distance between "sawteeth" (increasing from 0.26 in. at distance 1 in. behind trip to 0.57 in. at distance 2.6 in.)	0.43 in.
Ave. apparent width of formations (increasing from 0.1 in. at distance 0.7 in. behind trip to 0.8 in. at distance 2.7 in.)	0.39 in.

Results of Trip Experiment

Examination of the tabulated data together with the typical photograph at the top of Fig. 3 leads to two conclusions. The first conclusion is that a periodic impulse is introduced into the flow by the trip. The periodic formations behave like the vortices in a Kármán train, and pending further investigation may be considered as a special

case of the Kármán vortex train generated by the minute obstruction represented by the trip. In any case, they manifest definite periodicity.

A second conclusion, drawn from the top photograph of Fig. 3, is that it shows evidence of three-dimensional motion within the dye formations. It will be noted that these change form and manifest spanwise irregularities having a sawtooth appearance. The dye particles which, at the start, were spread uniformly have concentrated in the sawteeth during their rearward drift; that is, they have been subjected to lateral motion. In each formation, moreover, the lateral spacing between sawteeth shows a tendency toward uniformity; therefore, the sawtooth formation cannot be dismissed as random motion. The conclusion is reached that the formations embody three-dimensional motion, rather than a simpler two-dimensional motion in a single plane.

The evidence from the above test is that:

(1) The transition formations start with a regular periodicity.
(2) At any instant, a formation is under the influence of some form of uniform lateral segmentation having an appearance of three-dimensional motion.
(3) The rearward drift velocity increases downstream of the trip. The formations hesitate at the trip while building up, then accelerate into rapid motion prior to their dissipation.
(4) During the rearward drift prior to dissipation, the fore-and-aft spread, or width, of the formations increases.
(5) During the rearward drift, the longitudinal pitch-spacing between formations increases.

The above deductions relate to transition from laminar to turbulent flow when stimulated artifically by a trip. Regularly spaced formations are shown to intervene between the laminar and turbulent flow, introducing periodicity into the boundary-layer flow; and evidencing a three dimensional nature. It is not known to what extent the above phenomena apply to transition produced by natural causes, without a trip. Unfortunately the present apparatus will require some enlargement in order to reach the higher speeds required for determining this.

Second Experiment

Production of Boundary-Layer Vortices by Plate Deceleration

Meanwhile, a very interesting experiment has been made on a moving flat plate and has revealed a remarkable phenomenon caused neither by high speed nor by a trip, but merely by decelerating the plate. The experiment was prompted by previous experience with the behavior of jets. In a jet boundary layer it was found that discrete vortices took form following acceleration of the jet, and it was desired

to look for similar phenomena in the case of a moving flat plate. As it was impracticable to accelerate the still water in a tank, the alternative was to decelerate the plate instead. Such deceleration of the plate from steady motion would distort the boundary layer, in manner approximately similar to hypothetical acceleration of the water above the boundary layer; that is, it would cause momentary change of shape in the velocity gradient within the boundary layer, and establish a point of inflection in the gradient curve.

To investigate the effect on the boundary layer of decelerating a flat plate, temporary apparatus was set up and tested December 30, 1952, at which time the phenomenon now to be described was discovered by the writer. Permanent apparatus was then constructed to examine the phenomenon in detail; with this apparatus tests were made which corroborated and amplified the original findings. One of these tests will now be described as typical.

Apparatus for Plate Deceleration

In this experiment a submerged flat plate is moved edgewise through still water by the travelling carriage described previously. Unlike the preceding experiment, no trip is located on the plate. Since the decelerating weight is large compared with the frictional forces of the carriage, it furnishes a retarding force that is practically constant. It is neutralized at the moment of coming to a stop.

Test Procedure

In the experiment, the carriage and plate are brought into steady motion; a laminar boundary layer is formed on the plate; then the electric current is cut off so that the plate slows down and stops. Meanwhile, the motion picture camera is in operation from the start of the plate motion until some time after its stop; the camera records the behavior of the boundary layer as made visible by dye, until all the dye formations are dissipated. The film is next developed and mounted in the projector-analyzer, where micrometer measurements are taken off and tabulated. For the discussion of results, the data are shown in the form of curves, and selected frames of the films are reproduced in the form of photographic enlargements.

Generation of Spaced Columnar Vortices

The remarkable behavior of the boundary layer is shown in Fig. 4 Here the plate is decelerated from an initial steady speed of 1.27 fps. During plate deceleration, a grid of discrete columnar vortices takes form over the plate, their axes spanning the plate parallel to each other. Their appearance resembles the cloud formation of a "mackerel sky." They exist for a brief moment, during which they can be seen, by a quick

eye, to be in rotation. The laminar boundary layer has, in a fraction of a second, been converted into a formation of spaced rollers.

These photographs, it is to be recalled, show the plate in plan view looking down from above. The plate moves from right to left. The camera, mounted on the same carriage as the plate support, moves with the plate; therefore, in the photographs the plate appears as though fixed, with water flowing from left to right. Behavior of the boundary layer is made visible by six horizontal stripes of dye clinging to the plate surface; and the sequence of events is shown by the four photographs in Fig. 4. These have been enlarged from selected frames of the photo-recorder film record, and are described as follows:

The top photograph in Fig. 4 represents the situation during steady motion of the plate at velocity 1.27 fps. The dye stripes are smooth and even, denoting smooth laminar flow along their length. When the electric current is cut off, the plate begins to slow down with a deceleration averaging 1.42 fps^2. For a short period no change appears in the boundary layer, which continues laminar.

The second photograph of Fig. 4 shows the situation 0.73 sec. after cutting off the power. Spanwise vortices are beginning to take form, and to become visible where they cross the dye stripes. The plate is continuing to slow down, having advanced 1.6 in. beyond the position of the top photograph.

The third photograph shows the situation 0.91 sec. after cutting off the power. The columnar vortices appear as sharply defined dark lines lying spanwise of the plate and normal to its direction of motion. As compared with the second photograph these lines are perceptibly closer to the leading edge. The plate has now come to a stop 0.89 sec. after cutting off the power; that is, 0.02 sec. before the third photograph.

The bottom photograph shows the situation 1.10 sec. after cutting off the power. The fully-developed columnar vortices now appear as tubes about $\frac{1}{4}$ in. in diameter. They have "coasted" forward on the plate $\frac{1}{3}$ in. beyond their point of origin. They have expanded in size and, obviously, their axes have risen slightly away from the plate surface.

It is to be noted that the growth and dissipation of these vortices is very quick. They flash into existence and then out again in a fraction of a second. In the case of Fig. 4, their full maturity is reached within 0.18 sec. after birth.

Effect of Speed on Spacing Between the Vortices

The above test is one of several made at various velocities. At all velocities above 0.7 fps. in the series, a similar type of vortex grid

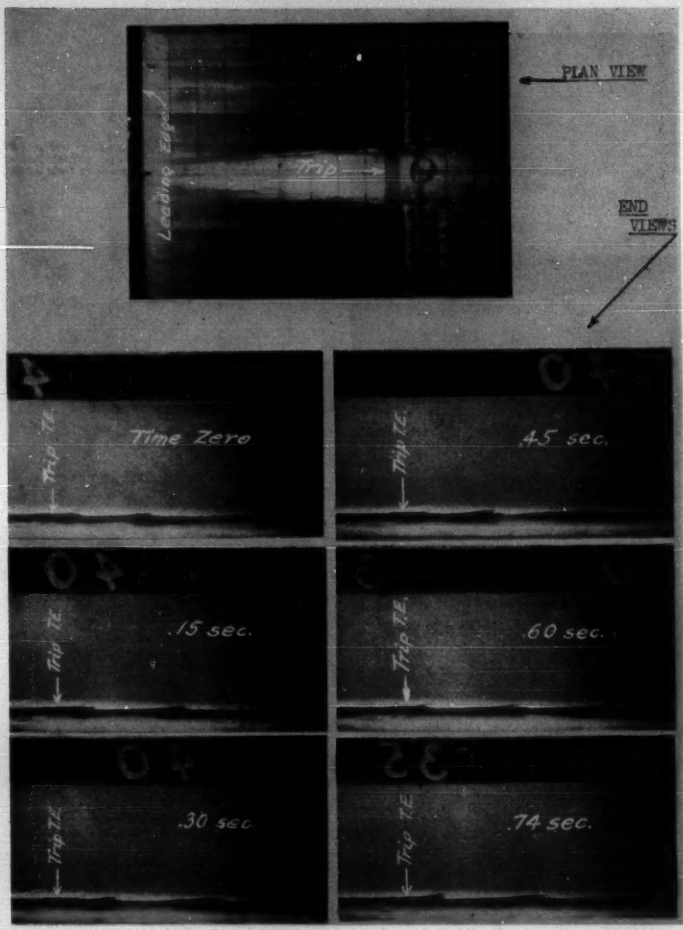
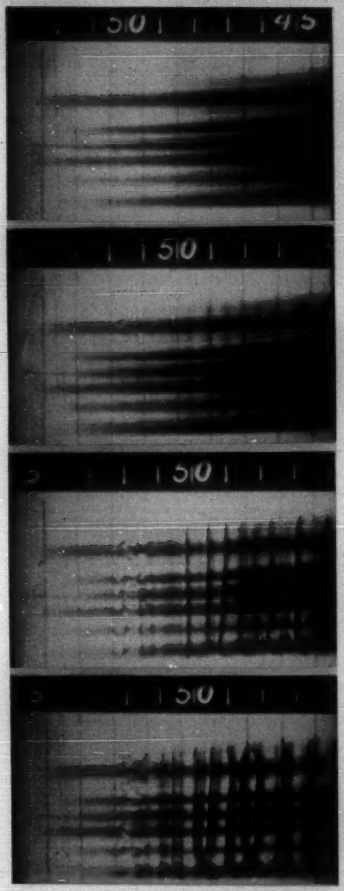


FIG. 3. Transition caused by a trip.

Top: Plan view, plate moving from right to left at 1.22 fps. through still water. Boundary layer to left of trip is laminar as shown by uniform distribution of dye. Periodic formations trail from trip as shown by jagged dye lines.
Below: Series of six film frames showing dye formations in end view. Speed, 0.64 fps. Motion from right to left.



Time, zero.
Plate in steady motion from right to left at 1.27 fps. The six longitudinal dye stripes appear smooth, indicating laminar flow along their length.

Time, 0.73 sec.
Columnar vortices are beginning to form, becoming visible where they cross the dye stripes.

Time, 0.91 sec.
Fully developed columnar vortices appear in their full length lying normal to the direction of motion of the plate. Plate has now stopped.

Time, 1.10 sec.
Tube-like columnar vortices are expanding and drifting to left toward leading edge of plate.

FIG. 4. Boundary-layer formations on decelerating flat plate.

Plan view looking from above on horizontal flat plate which moves edgewise from right to left through still water. No trip on plate. Photos enlarged from 16-mm. photo-recorder film reel.

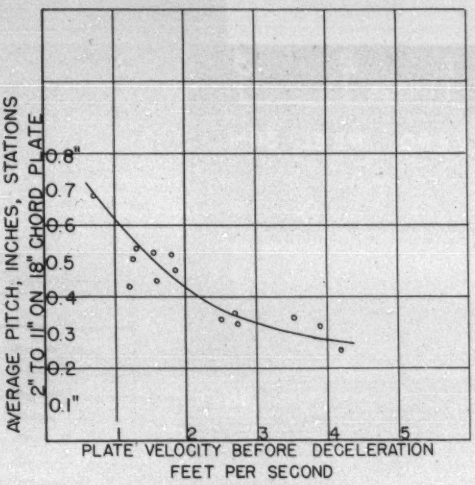


FIG. 5. Speed effect on average pitch between columnar vortices on a decelerated flat plate of 18-in. chord.

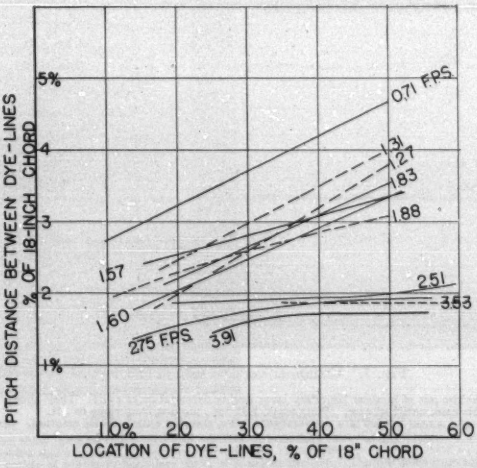


FIG. 6. Distribution of vortices on a decelerated flat plate at various velocities.

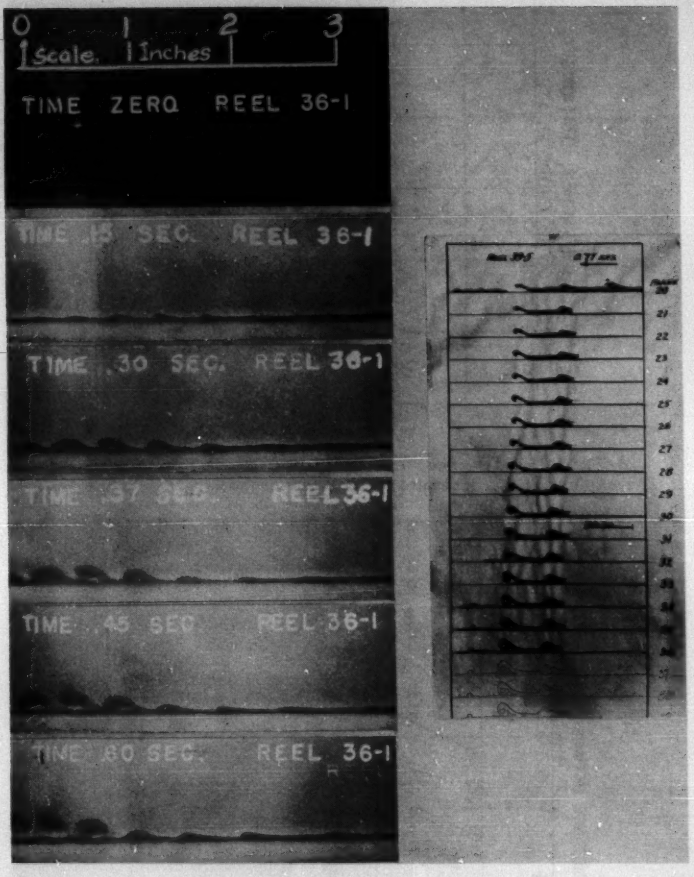

0 1 2 3
Scale. Inches
TIME ZERO REEL 36-1
TIME .15 SEC. REEL 36-1
TIME .30 SEC. REEL 36-1
TIME .37 SEC. REEL 36-1
TIME .45 SEC. REEL 36-1
TIME .60 SEC. REEL 36-1

FIG. 7. Columnar vortices seen in end view.

Above, left: Vortices rise out of laminar boundary layer during deceleration of plate. They appear as spiral scrolls rotating, in this case, anticlockwise. Plate speed 1.15 fps., moving from right to left.
Inset, right: Tracing of screen images of a deceleration vortex, showing anticlockwise rotation. Speed 0.77 fps.

FIG. 8. Columnar vortices seen in end view.

Left: Dye circles show cross-sectional shape of vortices in boundary layer of flat plate. They rotate clockwise. Plate is slowing down from 3-fps. velocity, moving from right to left.

Right: Mixing action of vortex in boundary layer of a submerged jet. The jet flows from right to left into still water at 0.05 fps. from a deep narrow nozzle of size $\frac{1}{4} \times 4$ in. The vortex is generated by a pressure impulse on the jet. It mixes the still water (dark) with the moving water (white) by wrapping them around each other.

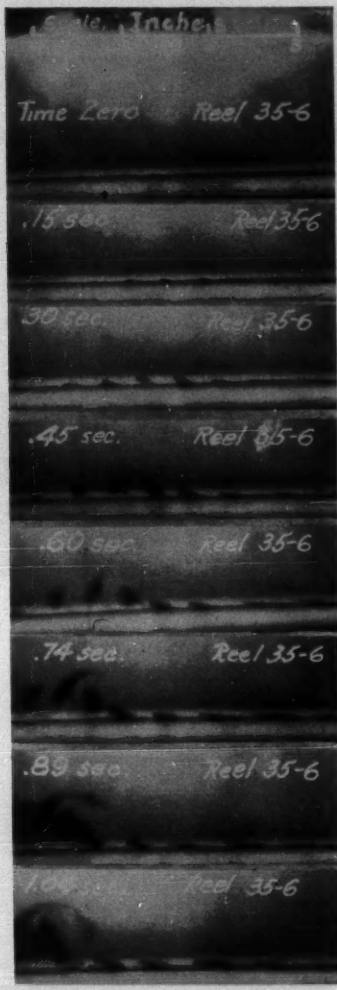


FIG. 9. Columnar vortices seen in end view.

During first 0.30 sec. the vortices rotate anticlockwise while advancing toward the leading edge. But clockwise translation is superposed on left hand vortex of later frames. The dye, arching up clockwise, shows this vortex in process of encircling and absorbing the two vortices behind it.
Plate motion is from right to left, decelerating from 1.15-fps. velocity.

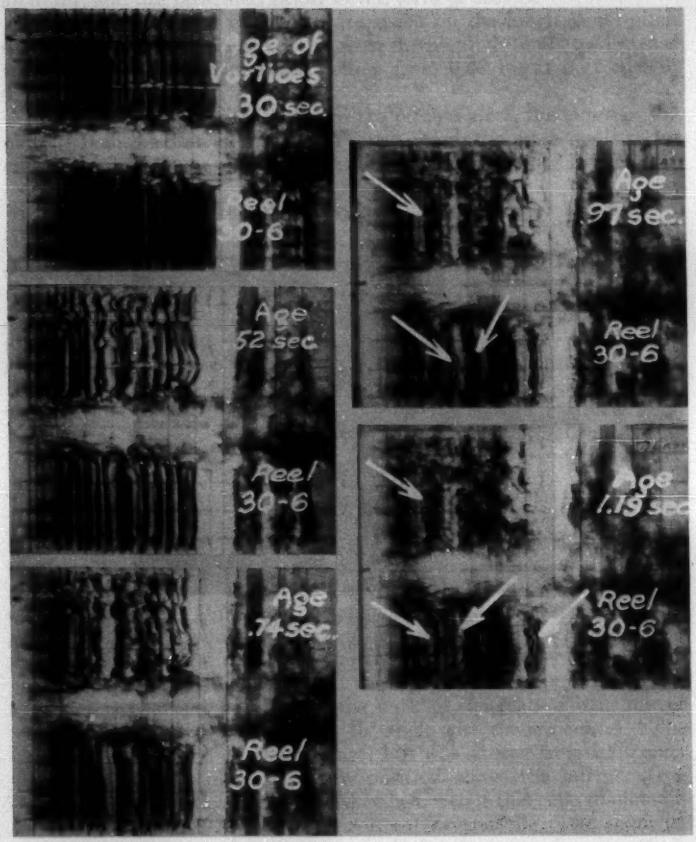


FIG. 10. Stage 3 of columnar vortices.

Film sequence showing change of shape from straight to wavy, just before disintegration. Plate speed before deceleration 1.22 fps. Motion is from right to left.

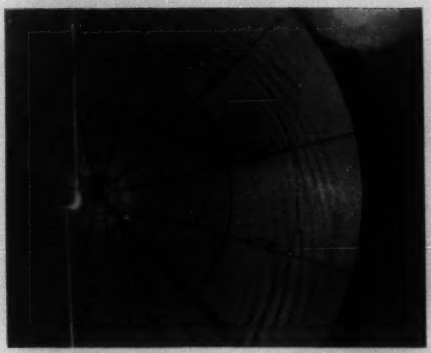


FIG. 11. Boundary-layer phenomena on rotating disc shown by dye tracer.

Plan view seen from above. Disc is horizontal, axis of rotation vertical. Disc diameter 24 in. Speed 0.71 rps., anticlockwise rotation. Submergence 3.4 in.

formation has been found. The results for the various speeds, recorded on film by the photo-recorder, have been evaluated in the projector analyzer, and are presented below in the form of curves.

Figure 5 shows the effect of plate speed on the longitudinal pitch spacing between the vortices. In general, the pitch tends to decrease when the plate speed increases, falling from 0.68 in. at 0.71 fps. to 0.31 in. at 3.91 fps.

Figure 6 gives the distribution of the pitches along the chord of the plate. It shows that, in a test at a given speed, the pitch tends to increase as its remoteness from the leading edge of the plate increases.

Relation Between Vortex-Spacing and Boundary-Layer Thickness

These characteristics of the vortex grids shown in Figs. 5 and 6 suggest a possible relationship between the vortex pitch spacing and the thickness of the laminar boundary layer. Thus, with speed increase and corresponding known decrease of boundary-layer thickness, the longitudinal pitch-spacing between vortices decreases. Again, with remoteness from the leading edge and corresponding known increase of the boundary-layer thickness, the longitudinal pitch-spacing between the vortices increases. It should be said that these deceleration vortices, as determined in other tests, do not form at all unless the boundary layer is laminar.

Direction of Rotation and Life History of the Vortices

The data of Figs. 4 to 6 were all derived from plan-view photographic records, in which the dye formations appeared in full length. But the plan-view records did not permit determination of direction of rotation of the formations. For such determination it was necessary to make additional tests in which the formations could be recorded end-on for analysis of their rotational characteristics.

To do this, the same plate and carriage were used but the optical system was changed. Alongside the path of the plate a long mirror was installed under the water, at a 46° angle with the horizontal. The camera was mounted on the carriage, but was shifted from its former position above the plate to a new position above the mirror. The camera pointed vertically downward as before, but this time the line-of-sight was reflected 92° by the mirror, to traverse the plate spanwise under water (with a 2° declination angle for the sake of perspective). Thus, by the use of a submerged mirror, the photographic record was able to show the dye formations substantially in end view.

Figures 7 to 9 show representative frames from some of the resulting end-view records, prepared by this means. The records provide data needed to determine the direction of rotation of the dye formations. Also, together with the plan view records, they provide a factual

life-history of the dye formations, and of the boundary-layer phenomena depicted by the dye formations.

The life-history of the deceleration vortices divides itself into four stages. These will now be described and each stage will be shown to have its own characteristics as follows:

Stage 1—On deceleration of a flat plate, spaced columnar vortices take form on the surface, and are seen to rotate.
Stage 2—The vortices swing upward along a widely sweeping circular path of clockwise direction.
Stage 3—The vortices while thus swinging upward undergo distortion along their length from straight columnar shape to wave-like shape.
Stage 4—The vortices disintegrate.

Stage 1 is illustrated by Fig. 7 which, at the left, shows six end-view photographs obtained in a test at velocity 1.15 fps. with the aid of a 46° mirror in the optical system as previously described. In these end-view photographs the cross-sectional shapes of the columnar vortices are seen to be spiral scrolls resembling teardrops. Their rotation during build-up appears to be anticlockwise (the plate motion being from right to left.)

To verify the anti-clockwise rotation, a similar but slower test is represented by the diagram at the right of Figure 7. The diagram is traced from film images of a test at 0.77 fps., in which, due to one particularly photogenic scroll, anticlockwise rotation is definitely recognizable. This spiral scroll, when examined in the projector-analyzer, is found to be rotating at approximately 4 rps. while drifting forward at about 0.16 fps.

Vortices appear in another form as shown by the eight enlargements at the left of Fig. 8. These have been obtained at a test velocity three times faster than the preceding end-view figures. In their end view the spaced vortices are well formed circles, this time rotating clockwise. A number of similar high-speed tests have been run and evaluated on the projector-analyzer to check the results of Fig. 8. In all tests made at the higher speed the dye circles show clockwise rotation. In most of these tests (but not all) the drift of the dye-circles is rearward, toward the plate trailing edge, with speed of drift ranging from 5 to 20 per cent of the pre-deceleration plate speed. Pending further tests, it is not known whether these clockwise formations may be a later stage of the anticlockwise teardrops, becoming noticeable at the higher velocity.

The onset of Stage 2 is shown by Fig. 9. Here the teardrop scrolls undergo bodily translation forward and upward, swinging away from their point of origin on the plate surface, and travelling along a circular path which, surprisingly, is clockwise. The procedure is fully developed

for the teardrop at the extreme left of the last frame. Note that the teardrop elongates while swinging upward; it sends out a tongue which arches overhead, curling backward in a circular path; and the sweep of this path is great enough to carry the dye half an inch above the plate surface.

The next stage, Stage 3, is of extreme interest. It is illustrated in Fig. 10, which is not an end-view study but a plan view, like Fig. 4. It is to be remembered that Fig. 4 shows the columnar vortex tubes in full length, and they appear as straight columns. But in Fig. 10 the tubes are no longer straight; instead, they have acquired a crooked wave-like appearance. The change occurs while the tubes are swinging away from the plate and along the circular path described above. The waviness increases as the tube, now crooked, swings around its circular path. The wave "crests" may lead the "troughs" more than 180°. Seen in plan view in Fig. 10 the appearance resembles sawteeth with rounded points. Development of the wavy shape has caused the length of the vortex to stretch out and the diameter to contract. The phenomenon can be seen better during test in the tank, where a quick eye can determine that the wavy shape of the dye tubes is three-dimensional.

Each columnar vortex, originally a straight two-dimensional formation, has now in Stage 3 become distorted into a three-dimensional formation. Thus three-dimensional, it is on the verge of disintegration.

In Stage 4 disintegration of the vortices is complete. The dye appears as a formless cloud without contrast or detail such as can be analyzed by the photo-recorder. The cloud has two characteristics. First, the dye has been raised high above the laminar boundary layer in which it originated. Its migration is not to be attributed to diffusion alone, for, as will be discussed later, diffusion plays little part. The dye motions in the first three stages are so fast that any diffusion effect may be ignored by comparison.

The second characteristic of Stage 4 is the uniformity with which the laminar boundary material has become distributed throughout the formless cloud. To demonstrate this uniformity of mixing, the photo-recorder was not used, but a special procedure, described below, was followed.

Mixing Characteristics of Deceleration Vortices

A striking characteristic of these deceleration vortices is their capacity for producing intimate mixing of the fluid particles. This was demonstrated during the experiments by using substitutes for dye in the following manner.

Instead of soluble dye, various insoluble powdered solids heavier than water were used. The primary object was to compare their behavior with soluble dye as a check for diffusion effect in the soluble

dye. The insoluble powders included Fullers Earth of particle size 8 microns; aluminum dust, 50 microns, with soap; and flowers of sulphur, 10 microns, with soap. Each of these was mixed with water to form an emulsion for introduction into the boundary layer as substitute for dye. They were subjected to the same procedure as the dye on a flat plate decelerating from a controlled steady speed.

In these tests, the various powders behaved about the same as dye in visualizing the boundary-layer vortices, with results approximately similar to those of Fig. 4. After the plate came to rest, however, and vortical motions subsided, a distinct departure from the behavior of dye occurred. Instead of generating a formless cloud like the dye, these solid insoluble particles settled back to the surface of the plate immediately after the vortical motion ended. It was at this point that the powerful mixing capability of the columnar vortices was disclosed; the carpet of solid particles now redeposited on the plate was, surprisingly, completely uniform and smooth—smoother even than had been attained when the emulsion at the start was spread over the plate surface.

This was an unexpected result, considering that prior to settling, all the powder had been concentrated in disconnected vortex rows which were separated from each other by clear water.

To explain this mixing capability, comments must be made at this point on the internal behavior of vortices in general. For this purpose, refer to the small photograph at the right of Fig. 8. This photograph represents a typical free vortex which was studied in a separate earlier series of tests. Although the vortex was not obtained on a flat plate, it is columnar like those on a flat plate, and its typical features serve to explain the mixing behavior of all vortices, including flat plate vortices.

Actually the typical vortex of Fig. 8 results from photographing the boundary layer of a jet of clear water surrounded by dyed still water. The vortex is one of a pair created in the laminar jet by impact of an infinitesimal pressure impulse. Note how the jet fluid (white) rolls up in alternate mixing layers with the surrounding still water (dark), like a jelly-roll. Particles of the jet water find themselves deflected laterally by distances equal to the diameters of their spiral paths. Likewise, particles of the surrounding still water are entrained into the vortex, and they too are displaced laterally by distances equal to the diameter of their spiral paths. The vortex achieves intimate intermixing of the moving and still particles in the boundary layer. The process occurs during the brief moment of birth of the vortex, when the energy absorption of the vortex is at its maximum. It is therefore a phenomenon which is dependent on the generation, rather than dissipation, of the vortex. It is a violent phenomenon, but an orderly one.

Returning now to the subject of columnar vortices which appear on a decelerated flat plate such as is shown by Fig. 4, we can apply to it the teachings of the preceding paragraph. We reach the conclusion

that the vortices appearing in the laminar boundary layer of a decelerated flat plate are the agency of the mixing activity.

Third Experiment

Boundary Layer on a Horizontal Disc Rotating in Still Water

The two foregoing experiments illustrate the use of the photo-recorder technique on a flat plate moving along a straight path under water. A third experiment will now be described in which the method is applied to a rotating disc.

For this experiment the same tank of still water mentioned above was used; but the former flat plate-propulsion apparatus was removed. Instead, a 24-in. diameter flat disc was mounted horizontally 3.4 in. under water to rotate about a vertical axis. The disc was powered to rotate and reach steady rotational motion after the first starting revolution.

During rotation, the phenomena within the boundary layer on the disc were made visible by dye. They were recorded from start to finish by the photo-recorder, whose camera was mounted in fixed position above the disc, pointed downward. Note that in this experiment the camera did not rotate with the disc; thus differing from the previously mentioned set-up wherein the camera moved with the flat plate. Note also that in this experiment there existed no trip such as had been used to stimulate transition in the first plate experiment.

Figure 11 shows the formation in the boundary layer resulting when the disc was rotated at 0.71 rps. Due to disc rotation, the boundary layer received both tangential and radial acceleration, increasing speed as it moved outward toward the rim of the disc.

In the photograph the center of the disc as far out as $\frac{3}{8}$ of the diameter is covered uniformly with dye which clings to the surface. This relative darkness of color in the central area denotes that the outward flow in this area is smooth and laminar.

The important feature of Fig. 11 is the appearance of curved dark lines, equally spaced around the annular region lying between $\frac{3}{8}$ and $\frac{7}{8}$ of the disc diameter. In this region, the dye flowing outward from the central portion of the disc has abandoned its uniformity of distribution. Instead, it has become concentrated in the sharply defined dark lines; these show up in strong contrast against the white clear spaces separating them. Outside the dark line region, from $\frac{7}{8}$ of the diameter to the rim, the area does not show any dye of sufficient concentration to record itself on the film sharply.

Results of Rotating Disc Test

In interpreting Fig. 11, it is to be remembered that the flow differs from that on the flat plate previously mentioned. On the previous plate moving in a straight line, the boundary layer was caused only by

surface friction, whereas here the boundary layer is subjected not only to surface friction, but also to centrifugal force; the boundary layer thus is increasingly accelerated as it moves outward toward the disc rim. The flow on the disc is different also because it encounters no "entry" disturbance from a leading edge as it moves outward from the central part of the disc.

Referring to the curved dark lines in the annular region $\frac{3}{8}$ to $\frac{7}{8}$ of the disc diameter, one can derive interesting information not revealed by the previous flat plate experiments. From projector-analyzer measurements of the film sequence represented by Fig. 11, the motion of these lines has been determined. They have a broadside outward movement, in direction normal to their arc of curvature. This direction is inclined about 10° forward of a disc radius. (The dark lines are not streamlines, although in the photograph they seem to invite such an interpretation.) The direction of motion is the same as of those particles of boundary-layer fluid which are remote from the disc surface. The evidence, therefore, is that the dark line formations stem from interaction between the boundary layer and the still water—not from interaction between the boundary layer and the frictional disc surface.

Regarding the disc-rim area outside the dark lines, the photograph offers little factual information; no satisfactory method has been found to make the flow in this region sharply visible. What information we do have is derived from observation by eye of cinematic projection of the film on a conventional motion picture screen. In the latter case, dye motion can be distinguished over the disc-rim area outside the dark lines. The dye disperses in thin irregular cloud-like masses, moving outward in direction normal to the dark lines. This final course of the dispersing dye lies obviously in a horizontal plane separated by a finite distance from the disc surface.

From projector-analyzer study of the film-frame series of which Fig. 11 is a part, the boundary-layer phenomena of Fig. 11 have been evaluated according to the following tabulation:

Reynolds Number at radius occupied by dark lines, based on radial distance and tangential velocity	204,000
Dark line direction of advance, deviation from radial	10°
Dark line speed of advance	0.46 fps.
Average pitch-spacing between dark lines	0.54 in.
Depth of submersion of disc under water	3.4 in.
Approximate number of dark lines around entire disc	22
Diameter of disc	24.0 in.
Revolutions per second of disc	0.71 rps.
Tangential velocity of disc at radius of dark lines	3.32 fps.

Effect of Speed of Disc

A series of runs has been made with the disc at various speeds. It is found that when the disc speed increases, the dark lines come into

existence closer to the center of the disc. Thus, at 0.66 rps., the dark lines occupy a ring whose inner diameter is 0.71 that of the disc and whose outer diameter is 0.85 that of the disc. But at 1.23 rps. these ring-diameter figures decrease to 0.52 and 0.64, respectively.

CONCLUSION

The foregoing experiments serve to illustrate the effectiveness of the new technique as a tool in boundary-layer research. A final word remains to be said regarding the role of this new technique in a field already well supplied with other research equipment in the form of wind tunnels. The reader may feel that the great wind tunnels meet all research requirements and that no new technique is needed. Indeed there are in existence several laminar flow wind tunnels, designed for boundary-layer studies and provided with air flow of minimum irregularities.

But this new technique goes even further than these. It has the advantage that it employs a fluid medium which is absolutely motionless, as previously mentioned; it is therefore free of those irregularities which, in a moving fluid, are inescapable however greatly reduced. In the new technique no disturbances exist to obscure the minute and extremely delicate phenomena of the boundary layer; thus the photographs in this paper reveal phenomena which would be lost in a wind tunnel. The new technique is therefore presented as a very effective tool, additional to the wind tunnel and supplementary to it, in the search for solution of the turbulence problem.

Acknowledgments

Acknowledgment of administrative courtesies which have facilitated these researches is made to: Dr. Frank L. Wattendorf, A.G.A.R.D.; Dr. F. M. Feiker, George Washington University; Mr. Omer Welling, C.A.A.; and Mr. Raymond B. Maloy, C.A.A.

Low Price Measuring Magnifier Uses Real Glass Reticle.—Edmund Scientific Corporation, Barrington, N. J., announces a new "vest-pocket" size version of its well-known pocket comparator. The new model is about half the size of the pocket comparator, making it easier to carry about on the job.

The big feature of the new comparator is that it employs a real glass reticle, instead of the film reticle found on other low priced miniature comparators. The reticle pattern is etched in the glass, and the etching is filled with pigment to make reading easier. The glass will not bend or warp, thus eliminating the possibility of damage or error in measuring.

The reticle pattern of the junior measuring magnifier is designed to compare hole diameters as well as take linear measurements. A special feature of the reticle is the thickness comparison scale, a series of parallel lines .002" to .007" apart. This makes it possible to measure directly the thicknesses of sheet materials such as paper or plastic. Such measurements, when performed by mechanical measuring devices, are sometimes inaccurate because of the compressibility of the materials measured. The optical measuring tool, on the other hand, gives a true reading because it does not require adjustments which bear on the surface measured.

The linear scale is given both in millimeters and decimal inches. The millimeter scale is 10 mm long, subdivided into units of .2 mm. The decimal inch scale is 0.5 in. long, subdivided into units of 0.005 in. Hole diameters are given in fractions from 1/64 to 1/16 in.; in decimals from 0.005 to 0.050 in.

The reticle is 21 mm. in diameter. This dimension is the same as standard microscope reticles, allowing the magnifier reticle to be removed from the magnifier and used in a microscope for measuring under greater magnification.

Both the reticle and the object to be measured are magnified six times when used in the junior measuring magnifier. The magnifying lens is accurate right to the very edge of the field. Light is admitted to the object and the reticle through the transparent Lucite walls of the reticle cell.

The complete unit measures only 2 in. long and 1 in. in diameter. It can be focused and locked in position to suit the vision of the user. It need not be retracted to fit in its carrying case—once it has been focused to suit it is ready for instant use at all times.

Cancer Diagnosis by Ultrasonics.—New medical, dental and industrial uses of sound, pitched too high for human ears were revealed recently to the national convention of the Institute of Radio Engineers at Kingsbridge Armory, Bronx, and the Waldorf-Astoria Hotel.

High-pitched sound, known as ultrasound to radio engineers, may prove to be a valuable ally in man's war on cancer. John M. Reid and John J. Wild, M.D., reported that ultrasonic energy has been successfully used at St. Barnabas Hospital, Minneapolis, to diagnose lumps in the human breast before operation. When the narrow sound beam encounters human tissue, a pattern of echoes is returned and displayed on a television picture tube.

Irregularities such as cancer, non-malignant solid tumors and liquid-filled cysts can be recognized from their characteristic pictures. Several echo photographs of typical lesions were shown for the first time at a session of ultrasonic specialists at the Belmont Plaza Hotel.

THEORETICAL COMMENTS ON THE PAPER OF MR. E. N. FALES

BY

TH. VON KÁRMÁN [1] AND C. C. LIN [2]

Mr. Fales' experiments revealed a new interesting case of vortex formation. When a flat plate moving in water was more or less abruptly decelerated, a row of parallel vortex columns appeared. We believe that the vortex formation can be traced to instability of the boundary layer during and after the deceleration. It is known that unstable oscillations develop in most shear layers, when the speed of motion is sufficiently high. In the case of a shear layer between two parallel streams of different velocity for example, Lessen[3] found that the flow becomes definitely unstable when the Reynolds number based on the thickness of the mixing region is of the order of 20. In this case, it is also known that the vortex sheet eventually rolls up into a periodic formation of discrete eddies. It may be expected, then, that the spacing between the individual vortices in the final stage will be approximately equal to the wave length of the initial unstable oscillations of the shear zone.

An analogous situation may exist in the present case, in which the boundary layer represents the shear layer. During the uniform motion the velocity distribution on the boundary layer is stable at the Reynolds

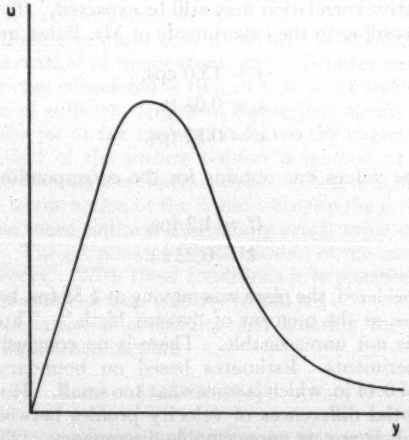


FIG. 1. A typical velocity profile.

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[3] M. LESSEN, Sc.D. Thesis, M.I.T. (1948); NACA TR No. 979 (1950).

numbers prevailing in the experiments. However after the sudden stoppage of the plate the velocity distribution is changing with time, and is of the general form shown in Fig. 1. This flow is certainly less stable than the profile corresponding to steady flow.

John E. Plapp recently computed the stability characteristics of a similar velocity profile given by the equation

$$u = A\eta(1 - \eta)^2, \quad \eta = y/\delta.$$

He found that the flow becomes unstable if the Reynolds number

$$R_\delta = \frac{U\delta}{\nu} > 408,$$

where $U = 4A/27$ is the maximum speed. At $R_\delta = 408$, the oscillation has a frequency f, wave length λ, and wave speed c as follows:

$$f = 0.207\ U/\delta,$$
$$\lambda = 2.10\ \delta,$$
$$c = 0.43\ U.$$

In the present experiments, the plate is not suddenly stopped, so that it still has a finite velocity at the time of vortex formation. However, a qualitative correlation may still be expected. Typical values of f, λ, and c, according to the experiments of Mr. Fales, are

$$f = 13.0 \text{ cps.}$$
$$\lambda = 0.04 \text{ ft.}$$
$$c = 0.52 \text{ fps.}$$

Based on these values one obtains for the corresponding values of U and δ

$$U = 1.2 \text{ fps.}$$
$$\delta = 0.23 \text{ in.}$$

In the case considered, the plate was moving at 1.55 fps. before stoppage, and at 0.72 fps. at the moment of "vortex birth." Thus the value of $U = 1.2$ fps. is not unreasonable. There is no conclusive value for δ from the experiments. Estimates based on boundary-layer theory yield a value of 0.14 in. which is somewhat too small. However, in view of the substantial differences of velocity profiles between theory and experiment, this is not an unreasonable discrepancy. Thus, the above analysis tends to support the point of view that the vortices are actually traceable to the instability of the flow after the stoppage of the plate.

The writers wish to thank Dr. W. D. Rannie and Mr. John E. Plapp for permission to use their unpublished results.

DROP SIZES FROM LOW SPEED JETS

BY

DARELL B. HARMON, JR.[1]

ABSTRACT

Previous theoretical work predicting the drop size to be expected from a slow speed jet is extended to the case in which the jet issues from a nozzle of sufficient length to assure fully developed laminar flow in the jet as it issues from the nozzle. It is shown that for a real liquid the jet contracts and the flow average velocity of the jet increases. Comparison of the theory with a single experimental result is made.

Recent measurements on the drops formed from a slow speed jet issuing from a long cylindrical nozzle made desirable an analysis of the theoretical drop sizes which might be expected. The works of Rayleigh (1)[2] and Weber (2) give the sizes which may be expected for any given jet diameter, but any reference of the drop sizes back to the nozzle diameters have to date assumed that the nozzle and jet sizes were equal. It seemed desirable to examine this assumption for the particular case which was being tested. To make this examination certain assumptions were made. These were: (*a*) no drag on the jet existed, and (*b*) no gravitational force was present.

The usual three conditions hold which are: (*a*) continuity of the jet mass, (*b*) conservation of momentum, and (*c*) conservation of energy. The particular case considered is that of a slow jet issuing from a cylindrical nozzle of sufficient length to assure that steady state laminar flow exists in the jet at the moment it leaves the nozzle. At first the destabilizing effect of the surface tension is ignored as is the energy which goes into forming the liquid surface. Then it is possible to conclude that due to the action of the liquid viscosity the jet velocity must tend to become more uniform and finally reach some constant value across the jet. The jet remains whole because of the assumption of no destabilizing forces. With these conditions it is possible to proceed to obtain the final diameter and velocity of the jet.

Using the equation of continuity and ignoring the slight volume change of the liquid, one obtains

$$V_A d_0^2 = V_f d_f^2. \tag{1}$$

From the conservation of momentum we may write

$$M_0 = M_f, \tag{2}$$

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[2] The boldface numbers in parentheses refer to the references appended to this paper.

where, taking the momentum per second past the nozzle outlet,

$$M_0 = \int_{\text{jet}} V dm = \int_{\text{jet}} V \rho V dA. \tag{3}$$

Integrating Eq. 3 for a laminar velocity distribution, one obtains

$$M_0 = \frac{\pi}{3} \rho V_A^2 d_0^2. \tag{4}$$

The final momentum is

$$M_f = \rho V_f^2 \frac{\pi}{4} d_f^2. \tag{5}$$

From Eqs. 2, 4, and 5 is obtained

$$\frac{V_A^2 d_0^2}{3} = \frac{V_f^2 d_f^2}{4}. \tag{6}$$

Substituting Eq. 1 in Eq. 6 gives

$$d_f = \frac{\sqrt{3}}{2} d_0. \tag{7}$$

Solving for the final velocity, one finds

$$V_f = \frac{4}{3} V_A. \tag{8}$$

It is evident from the last two equations that the jet contracts as the liquid proceeds, and that the *average* velocity increases.

Since energy is also conserved, the total energy which is dissipated by the viscous action may also be computed. The initial kinetic energy is

$$KE_0 = 2 \left(\frac{1}{2} m V_A^2 \right) = m V_A^2. \tag{9}$$

The final kinetic energy is

$$KE_f = \frac{1}{2} m V_f^2 = \frac{8}{9} m V_A^2, \tag{10}$$

when Eq. 8 is used for a substitution. It is apparent that one-ninth of the total kinetic energy is dissipated viscously, or goes into formation of jet surface. This energy change is large compared with that which

might be expected to go into the formation of the jet surface, therefore a majority of the loss must be due to viscous action.

Approximate calculations show that for a liquid with small viscosity such as water, the time taken to assume the constant velocity across the jet is in the order of twenty seconds for a small jet. It is well known that slow speed jets break up into drops in only a small fraction of this time. It is evident, however, that, since drag is small for the slow jets, the drop velocity after the jet has broken up must be the velocity given in Eq. 8. One can conclude, therefore, that the destabilizing effect of the surface tension also causes a rapid change in the velocity distribution across the jet. Furthermore, since the velocity of the drops is given by Eq. 8, the diameter of the jet must be given by Eq. 7 prior to the final breakup into drops of the jet. If these conclusions were not true for the drag-free case, then continuity in the jet, and conservation of momentum would not take place.

Utilizing the conclusions of the preceding paragraph, it is possible to compute the drop size to be expected in the resulting spray. For a jet of low viscosity, one may use the optimum breakup wave length of Rayleigh (1), which is

$$L_{\text{opt.}} = 4.51\, d_f. \tag{11}$$

Since the jet wave length which separates off must go into a single spherical drop, one can use the fact of continuity to determine the final drop diameter. It is

$$d_d = 1.89\, d_f, \tag{12}$$

or relating the drop diameter to the nozzle diameter:

$$d_d = 1.63\, d_0. \tag{13}$$

The derivation made here may account for some of the variation in the published results for measured drop sizes from slow speed jets (3). The previously used value of drop diameter expected from a jet of low viscosity has been slightly greater than twice the nozzle diameter.

When the viscosity is taken into account, the drop diameter becomes (2)

$$d_d = 1.63\, d_0\, (1 + 3z)^{\frac{1}{3}}, \tag{14}$$

where

$$z = \frac{\eta}{\sqrt{\rho \sigma d_0}}. \tag{15}$$

The only test which has been made of the previous theory was on a nozzle for which the calculated drop size was 0.0499 cm. The "volume-to-surface" mean drop size found was 0.0528 cm. and the volumetric

mean drop diameter found was 0.0516 cm. The instrument used has not had enough tests made yet to determine the extent of the errors involved in the measured values so the absolute value of the comparison is undetermined.

NOMENCLATURE

A = area
d = diameter or derivative
KE = kinetic energy
L = wave length of disturbance of jet
M = momentum per second
m = mass per second
V = velocity
η = absolute viscosity
ρ = density
σ = surface tension

Subscripts

A = average velocity of jet initially
f = final conditions of steady state
0 = initial conditions at orifice
d = drop

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LARGE DEFLECTIONS OF SIMPLY SUPPORTED BEAMS

BY

K. T. SUNDARA RAJA IYENGAR [1] AND S. K. LAKSHMANA RAO [1]

SUMMARY

Large deflections of simply supported beams have been studied when the transverse loading consists of a uniformly distributed load plus a centrally concentrated load under the two cases, (1) the reactions are vertical, (2) the reactions are normal to the bent beam together with frictional forces. The solutions are obtained by the use of power series expansions. This method is applicable to all cases of symmetrical loading in beams.

INTRODUCTION

In the classical theory of the deflection of beams we start with the Bernoulli-Euler relation connecting the bending moment in the beam with the curvature, but neglect all terms of degree higher than the first in the expression for the curvature. Results based on this simple theory however cannot be applied in the case of large deflections as they may lead to unconservative errors. Barten (1)[2] and Bisshopp and Drucker (2) provided large deflection solutions for the cantilever with a concentrated load at the free end. Large deflection solution for the simply supported beam with a central concentrated load was given by Conway (3) and some formulas for beam columns have been recently proved by Saelman (4). In all these cases, the equations are directly integrated leading to solutions expressible in terms of elliptic integrals. Rohde (5) has expanded the slope in a power series of the arc length to study the large deflections of a cantilever with uniformly distributed load. This method is found to be of wide applicability in the solution of large deflection problems and can be very well employed even in the problems treated in References 1–4.

In the present paper we are concerned with the large deflections of simply supported beams. Using the method of power series expansions, we study the deflections of beams carrying a uniformly distributed load plus a central concentrated load, in the following two cases:

(1) when the reactions at the ends are assumed vertical,
(2) when the reactions at the ends are assumed normal to the bent beam together with tangential frictional forces opposing deflections.

The problem in (3) is clearly a particular case of that treated here.

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[2] The boldface numbers in parentheses refer to the references appended to this paper.

We take beams of uniform cross-section. The following basic assumptions are made: (1) the deformations are elastic; (2) the bending does not alter the length of the beams; and (3) the supports are at a fixed distance apart and at the same horizontal level.

Case 1

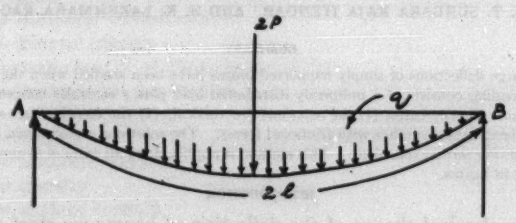

FIG. 1.

The Bernoulli-Euler relation, *viz.*,

$$\frac{1}{\rho} = \frac{d\phi}{ds} = \frac{M}{B}, \tag{1}$$

leads to

$$B\frac{d^2\phi}{ds^2} = \frac{dM}{ds} = [q(l-s) + P]\cos\phi \tag{2}$$

where $B = \dfrac{EI}{1-\sigma^2}$, s = arc length measured from A, q = load intensity, $2P$ = central concentrated load, ϕ = inclination and $2l$ = length of the beam. The boundary conditions are

$$\begin{aligned} &\phi = 0 \quad \text{at} \quad s = l; \\ &\frac{d\phi}{ds} = 0 \quad \text{at} \quad s = 0,\ s = 2l; \\ &\phi = \alpha \quad \text{at} \quad s = 0. \end{aligned} \tag{3}$$

The nonlinear equation (2) does not lend itself to any direct solution. Put

$$\phi = a_0 + a_1 s + a_2 s^2 + \cdots. \tag{4}$$

From (3) we have

$$a_0 = \alpha, \quad a_1 = 0$$

so that

$$\phi = \alpha + \beta$$

where

$$\beta = a_2 s^2 + a_3 s^3 + \cdots. \tag{5}$$

We may write from (2)

$$B(2a_2 + 6a_3 s + \cdots) = [q(l - s) + P]\cos(\alpha + \beta). \tag{6}$$

Expanding $\cos\beta$, $\sin\beta$ in the right hand side and comparing coefficients, we find

$$a_2 = \frac{(ql + P)\cos\alpha}{2B}, \quad a_3 = -\frac{q\cos\alpha}{6B},$$

$$a_4 = \frac{(ql + P)^2 \sin\alpha\cos\alpha}{24B^2},$$

$$a_5 = \frac{q(ql + P)\sin\alpha\cos\alpha}{30B^2}.$$

.....

Using the condition $\phi = 0$ at $s = l$ and introducing the non-dimensional parameters

$$K_u = \frac{ql^3}{B}, \quad K_c = \frac{Pl^2}{B}, \tag{7}$$

$$-\alpha = \begin{cases} \dfrac{K_u\cos\alpha}{3} + \dfrac{K_c\cos\alpha}{2} - \dfrac{K_u^2\sin\alpha\cos\alpha}{72} \\ -\dfrac{K_uK_c\sin\alpha\cos\alpha}{20} - \dfrac{K_c^2\sin\alpha\cos\alpha}{24} + \cdots. \end{cases} \tag{8}$$

For a first approximation

$$\alpha = -\frac{K_u}{3} - \frac{K_c}{2}$$

which is in agreement with the small deflection theory. The maximum deflection y_m is given by

$$\frac{1}{l}y_m = \frac{1}{l}\int_0^l \sin\phi\, ds = \frac{1}{l}\int_0^l (\sin\alpha\cos\beta + \cos\alpha\sin\beta)ds$$

$$= \sin\alpha + \left(\frac{K_u}{8} + \frac{K_c}{6}\right)\cos^2\alpha \tag{9}$$

$$+ \left(-\frac{K_u^2}{60} - \frac{17}{360}K_uK_c - \frac{K_c^2}{30}\right)\sin\alpha\cos^2\alpha + \cdots.$$

In the simple theory

$$\frac{y_{max}}{l} = \frac{y_s}{l} = \alpha + \left(\frac{K_u}{8} + \frac{K_c}{6}\right) = -\frac{5}{24}K_u - \frac{K_c}{3}.$$

Choosing a definite ratio of $\frac{K_u}{K_c} = n$, we may determine K_u and K_c for different assumed values of α from Eq. 8 and y_m from Eq. 9. $\frac{y_m}{2l}$, $\frac{y_s}{2l}$ and $\frac{y_m}{y_s}$ can be plotted against K_u or K_c. Putting $K_c = 0$ in Eqs. 8 and 9, we have the solution for a beam with a uniformly distributed load. If $K_u = 0$, Eqs. 8 and 9 provide the solution for the case of a centrally concentrated load, treated in a quite different way in Conway's paper (3).

Case 2

When the forces at the ends consist of reactions normal to the bent beam R plus tangential forces $\mu R (\mu = \tan \lambda$ is the coefficient of friction), we have the case shown in Fig. 2. The resultant vertical and horizontal

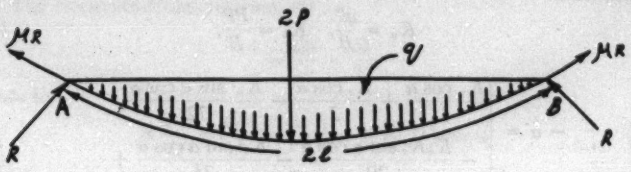

FIG. 2.

forces

$$ql + P = R\cos\gamma + \mu R \sin\gamma,$$
$$Q = R\sin\gamma - \mu R\cos\gamma,$$

giving

$$Q = (ql + P)\tan(\gamma - \lambda).$$

The bending moment equation leads to

$$B\frac{d^2\phi}{ds^2} = (ql + P - qs)\cos\phi + \tan(\gamma - \lambda)(ql + P)\sin\phi. \quad (10)$$

The boundary conditions are

$$\phi = 0 \quad \text{at} \quad s = l;$$
$$\frac{d\phi}{ds} = 0 \quad \text{at} \quad s = 0, s = 2l; \quad (11)$$
$$\phi = \gamma \quad \text{at} \quad s = 0.$$

Proceeding as before, put

$$\phi = b_0 + b_1 s + b_2 s^2 + \cdots.$$

Here $b_0 = \gamma$, $b_1 = 0$ so that

$$\phi = \gamma + \delta$$

where

$$\delta = b_2 s^2 + b_3 s^3 + \cdots.$$

Using the same procedure as in Case 1, we obtain

$$\phi = \begin{cases} \gamma + \dfrac{(ql + P)\cos\lambda}{2B\cos(\gamma - \lambda)} s^2 - \dfrac{q\cos\gamma}{6B} s^3 \\ - \dfrac{(ql + P)^2 \sin\lambda\cos\lambda}{24B^2\cos^2(\gamma - \lambda)} s^4 + \cdots. \end{cases}$$

From the condition $\phi = 0$ at $s = l$ we have

$$-\gamma = K_u \left\{ \frac{\cos\lambda}{2\cos(\gamma - \lambda)} - \frac{\cos\gamma}{6} \right\} + K_c \left\{ \frac{\cos\lambda}{2\cos(\gamma - \lambda)} \right\}$$
$$+ K_u^2 \left\{ - \frac{\sin\lambda\cos\lambda}{24\cos^2(\gamma - \lambda)} + \frac{\cos\gamma\sin\lambda + 3\sin\gamma\cos\lambda}{120\cos(\gamma - \lambda)} - \frac{\sin\gamma\cos\gamma}{180} \right\} + \cdots.$$

The maximum deflection $y_m = \int_0^l \sin\phi\, ds$ leads to

$$\frac{y_m}{l} = \sin\gamma + K_u \left(\frac{\cos\gamma\cos\lambda}{6\cos(\gamma - \lambda)} - \frac{\cos^2\gamma}{24} \right) + K_c \cdot \frac{\cos\gamma\cos\lambda}{6\cos(\gamma - \lambda)} + \cdots.$$

In the simple theory, the maximum deflection y_s is given by

$$\frac{y_s}{l} = \gamma + K_u \left(\frac{\cos\lambda}{6(\cos\lambda + \gamma\sin\lambda)} - \frac{1}{24} \right) + \frac{K_c}{6} \left(\frac{\cos\lambda}{\cos\lambda + \gamma\sin\lambda} \right)$$

where γ is a root of the equation

$$-\gamma = \frac{(K_u + K_c)\cos\lambda}{2(\cos\lambda + \gamma\sin\lambda)} - \frac{K_u}{6}.$$

Proceeding as in Case 1, it is possible to compute the values of y_m for different values γ for any definite ratio of K_u, K_c. These values may be employed for plotting y_m against K_u or K_c.

Acknowledgment

It is a pleasure to thank Professor N. S. Govinda Rao for his continued interest in this investigation and constant encouragement.

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NOTES FROM THE NATIONAL BUREAU OF STANDARDS

ZONE MELTING APPARATUS

An automatic laboratory-type zone melter recently constructed at the National Bureau of Standards combines versatility and dependability with unusual simplicity and ease of operation. The device is now being used in the Bureau's solid state physics laboratory to obtain extremely high-purity semi-conducting materials.

The zone melting process has been used to purify metals for several years and is now a familiar industrial and scientific tool. By this process it is possible in some cases to obtain such a high degree of purity that the remaining impurities are almost undetectable by present analytical methods. By the process it is also possible to blend in evenly a specific amount of another metal to obtain a desired alloy. Although a number of zone melting devices somewhat similar to the NBS apparatus are in operation in other laboratories, none of these has been fully described in the literature.

In the NBS zone melter, the solid material to be purified is placed in a fused silica or carbon boat within a vycor tube. A water-cooled induction coil, concentric with the vycor tube, is then made to pass slowly along the length of the solid material. The resultant heating effect produces a small molten zone in the bar of material. This molten zone moves along the length of the bar with the coil, causing a continuous separation of impurities at the zone boundaries. The separation occurs in such a manner that after the material has been melted a number of times, the impurities tend to concentrate at one end of the bar. The apparatus is designed so that the operation can be carried out either in a vacuum or in an inert atmosphere.

The heater coil, powered by a commercial 5-kilowatt unit, is mounted on a three-wheeled carriage which provides a useful travel of 18 in. The wheels, ball bearing-mounted, engage and are guided by two $\frac{3}{4}$-in.-diameter rods or tracks. The motion is supplied to the carriage by a $\frac{1}{2}$-in.-diameter, 20-pitch, steel lead screw and a porous bronze nut. The nut is rubber-mounted on the center line of the carriage.

For small melts only one heating coil is used on the carriage, but provision has been made for mounting two or more coils in series if required. The coil consists of four turns of compactly wound $\frac{1}{8}$-in. copper tubing. It is slightly more than $\frac{1}{4}$ in. long and has an inner diameter of approximately $1\frac{1}{8}$ in. A flow switch in the water line cuts off the heater power in case of water failure.

For the forward motion of the carriage, the lead screw is driven

through a friction clutch and reduction gears—100/1 worm and worm gear and 72/7 spur gears—by a 1/40-horsepower shunt-wound d-c. motor. The speed of the motor is nominally 1140 rpm., but it can be varied from about 240 rpm. to approximately 2000 rpm. by decreasing the voltage and changing the field resistance. This results in a possible variation in the rate of zone travel of from $\frac{3}{4}$ in./hr. to 6 in./hr.

Adjustable stops on a simple push-pull rod, which actuates a toggle switch, limit the length of travel of the work coil. The stops may be set to allow a minimum travel of one inch or a maximum of 18 in. When the coil has reached a predetermined point, a fork on the carriage engages one of the stops and the switch is closed. This starts a $\frac{1}{10}$-horsepower intermittent-duty motor which is directly coupled to one end of the lead screw. The rotation of the screw is reversed, and the carriage returns to its initial position at the rate of 75 in./min. This increased speed is sufficient to prevent the specimen from melting on the return portion of the cycle even though the heater current is not interrupted. When the carriage has reached the initial position, the fork engages the other of the two stops, causing the rod to open the switch and to stop the return motor.

A feature of the NBS device is a simple spring-loading friction clutch. This permits the slow-speed drive motor to operate continuously, even during the rapid return of the carriage, thus eliminating the need for a more complex clutch and switching arrangement. An automatic counter registers each complete cycle.

For convenience all controls are compactly arranged in a 6×7×10-in. metal cabinet. Included are the controls for the d-c. motor, the transformer for the a-c. motor, switches to reverse either motor, and the fuses. Input to this unit are 110 volts both alternating and direct current. The connection is made through an eight-conductor cable and a plug and socket.

Since its construction the Bureau's apparatus has been in almost constant operation and has performed very satisfactorily with a minimum of attention. It is now being used at NBS to produce a series of intermetallic compounds formed between the metal antimony and the metals indium, gallium, or aluminum.

NUCLEAR ENERGY NEWS

PROPOSALS FOR POWER DEMONSTRATION REACTOR PROGRAM

The Atomic Energy Commission announced early in April that four proposals had been received from public and private organizations under the Power Demonstration Reactor Program that the AEC had announced in January (see March JOURNAL, page 240). The intent of this program is to advance the time when nuclear power will become economically competitive. Mr. Strauss, Chairman of the Atomic Energy Commission, in commenting on this response stated that "the significant point is the extent to which the proposers are prepared to risk their own capital."

The four proposals will be considered on a competitive basis within the limits of the funds and materials that may be available to the Commission for this program. Obligational authority of $75 million for general acceleration of the civilian power program has been included in the AEC budget request for fiscal year 1956. To carry on their projects successful proposers must qualify as licensees under the provisions of the Atomic Energy Act of 1954.

The proposals received were:

1. Boiling water reactor plant of 180,000 kilowatts capacity, to be completed in 1960, proposed by the *Nuclear Power Group*, composed of: American Gas & Electric Service Corporation, New York; Bechtel Corporation, San Francisco, Calif.; Commonwealth Edison Company, Chicago, Ill.; Pacific Gas and Electric Company, San Francisco, Calif.; Union Electric Company, St. Louis, Missouri.

2. Light water moderated and cooled reactor plant of 100,000 kilowatts capacity, to be completed in late 1957; proposed by the *Yankee Atomic Electric Company* of Boston, members of which are: New England Power Company, Boston, Mass.; Connecticut Light and Power Company, Hartford, Conn.; Boston Edison Company, Boston, Mass.; Central Maine Power Company, Augusta, Maine; Hartford Electric Light Company, Hartford, Conn.; Connecticut Power Company, Hartford, Conn.; Western Massachusetts Electric Company, Greenfield, Mass.; Public Service Company of New Hampshire, Manchester, N. H.; Montaup Electric Company, Fall River, Mass.; New Bedford Gas and Edison Light Company, New Bedford, Mass.; Cambridge Electric Light Company, Cambridge, Mass.; Central Vermont Public Service Corp., Rutland, Vermont.

3. Fast breeder reactor plant with 100,000 kilowatts capacity to be completed in late 1958, proposed by *Atomic Power Development Associates*, consisting of the following companies: Central Hudson Gas

and Electric Corporation, Poughkeepsie, New York; Cincinnati Gas and Electric Corporation, Cincinnati, Ohio; Consumers Power Company, West Jackson, Michigan; Delaware Power and Light Company, Wilmington, Delaware; Detroit Edison Company, Detroit, Michigan; Long Island Lighting Company, Mineola, New York; Philadelphia Electric Company, Philadelphia, Pa.; Rochester Gas and Electric Corporation, Rochester, New York; Toledo Edison Company, Toledo, Ohio.

4. Sodium graphite reactor plant of 75,000 kilowatts capacity, to be completed in 1959; proposed by the Consumers Public Power District of Columbus, Nebraska.

The four proposals included requests that the Government assist in providing adequate public liability and property damage insurance.

In addition to the power reactor projects contemplated in the proposals under the Power Demonstration Reactor Program, the Consolidated Edison Company of New York has applied to the AEC for a license to build and operate entirely with private capital a nuclear power plant with a capacity of 250,000 kilowatts which the company estimates will cost about $55,000,000. The reactor for this plant would be light water cooled and moderated. It would take about five years to build.

STUDIES UNDER INDUSTRIAL PARTICIPATION PROGRAM

Four studies under the Industrial Participation Program of the Atomic Energy Commission were approved late in March. They are as follows:

1. Combustion Engineering, Inc. will study design and evaluation of large reactors for central station power production and of small size reactors for special applications, design of reactor fuel elements, and development of fuel element fabrication processes.

2. The Baldwin-Lima-Hamilton Corporation of Philadelphia, Pennsylvania and the Denver and Rio Grande Railroad of Denver, Colorado will make a study of a nuclear powered reciprocating engine under the AEC's Industrial Participation Program. The companies will weigh the engineering, technical and economical aspects of a nuclear-powered engine of this type and make recommendations concerning the role industry might undertake in carrying out the development. There are many potential applications of a power generating unit of the type under study, including locomotive propulsion.

3. General Dynamics Corporation will investigate nuclear power equipment such as small power reactors and specially designed components of reactor systems with a view to manufacturing such products. The company will also explore various problems related to the peaceful applications of nuclear power such as decontamination services, utilization of by-product radiation, instrumentation, waste disposal, and

the materials and equipment required to handling these problems. The company estimates it will spend $200,000 on the study which will take one year.

4. The National Rural Electric Cooperative Association will study the economic and engineering practicability of various atomic power reactor designs in view of the specialized needs of the rural electric systems. This would include a study of the reactors to be constructed and operated in the AEC's five-year research and development program, the Army Package Power Reactor and any other experimental power reactors which may be designed or built within the AEC program of industrial participation.

BASIC REGULATIONS FOR CIVILIAN ATOMIC INDUSTRY

The Atomic Energy Act of 1954 provided that the Atomic Energy Commission prepare regulations governing the activities of private and public organizations and persons in the development and utilization of atomic energy for peaceful purposes. The first three regulations were published by the Commission in the Federal Register in mid-April to give the public a thirty-day period in which to submit written comments before the regulations are officially promulgated.

The proposed regulations deal with the following general subjects: distribution of special nuclear material, licensing of facilities for the production and utilization of fissionable material, export controls, and the safeguarding of restricted data concerning atomic energy.

In developing the proposed regulations the AEC made use of comments and suggestions from advisory groups representing the principal segments of industry that will be affected by the regulations.

U. S. NUCLEAR REACTOR FOR GENEVA CONFERENCE

The United States will build an operating research reactor at Geneva, Switzerland, for demonstration at the United Nations International Conference on August 8–20, 1955. The project, expected to be a major exhibit feature of the Conference, has been made possible through the cooperation of the Government of Switzerland and the Secretary General of the United Nations.

The exhibit will enable visiting scientists and technicians to observe a reactor which provides excellent facilities for a variety of cross-section measurements, experiments with neutrons and gamma rays, including shielding studies and production of radioisotopes.

The reactor will be of the "swimming pool" type successfully operated at the AEC's Oak Ridge National Laboratory for several years. The name comes from the fact that the reactor is immersed in a pool of water, 10 feet in diameter and 20 feet deep, which affords an effective safety shield against radiation.

The fuel will be fuel grade uranium enriched in isotope 235 to about

20 per cent. About 5 kilograms of U-235 will be required. This is the type of fuel other nations can obtain from the United States under the atoms-for-peace program.

The reactor will be housed in a temporary prefabricated metal building designed especially to enable the delegates and visitors at Geneva to see the reactor in operation. A small platform will be built on top of the reactor, from which a lecturer can direct demonstrations and explain the operation of the machine. The housing structure will be designed to accommodate a constant flow of visitors observing the operation of the reactor.

Qualified scientists and technicians will be allowed to operate the machine, using the controls to start, maintain and stop a nuclear chain reaction within the reactor. During these experiments, known as criticality tests, the familiar blue glow of the irradiated fuel elements will be visible in the water.

The project for the Geneva Conference will be carried out by Oak Ridge National Laboratory. The estimated cost is $350,000. The reactor will be tested at Oak Ridge and then dismantled and shipped to Geneva. The reactor and its fuel will be at all times under the control and custody of the AEC.

WESTINGHOUSE NUCLEAR TEST REACTOR

The world's first industry-owned, nuclear materials test reactor will be built by Westinghouse Electric Corporation at a cost of six and one-half million dollars, it was announced in April by Gwilym A. Price, Westinghouse president. Westinghouse asked approval of the Atomic Energy Commission to locate the reactor center on the company's 550 acre site near Blairsville, Pa. 40 miles east of Pittsburgh. The Westinghouse Test Reactor will operate in the range of 10,000 kilowatts.

"This reactor will help break through what we think is the number one bottleneck in America's progress in nuclear power by providing needed new facilities to test reactor fuel elements and other components of atomic power plants under actual operating conditions," the Westinghouse president declared.

"Up to now, organizations such as Westinghouse, working on the development of nuclear power plants, have had to depend on the limited radiation facilities at the AEC's materials testing reactor (MTR) in Idaho and other Government reactors as well as Canada's Chalk River reactor," he continued. "Our reactor center's high power materials testing reactor will be built entirely without Government subsidy or guarantee of Government work and we expect it to be in full operation within two years. It will be known as the 'Westinghouse Test Reactor (WTR)' and when completed it is expected to have the

largest physical capacity for full-scale testing of atomic power plant components of any test reactor in the United States.

The Westinghouse Test Reactor will be of an advanced design and will use highly enriched uranium as the power source, and water as moderator and coolant. The test holes into which materials may be placed to be irradiated will afford greater test capacity and flexibility than any reactor yet built in the United States. Large test thimbles will pierce the nuclear core itself and will be big enough to test large size fuel specimens. The reactor will be housed inside a vapor-tight steel shell and will have built-in safety features, which will make it "inherently safe."

The remainder of a proposed "reactor center" at Blairsville will include a laboratory constructed near the reactor building to handle and process radioactive materials resulting from the reactor test, as well as general offices, and facilities for heat and power. Initial plans call for the reactor center to employ some 100 people.

THE FRANKLIN INSTITUTE

MINUTES OF THE STATED MEETING

May 18, 1955

At the dinner in Franklin Hall, prior to the meeting in the Lecture Hall, tests started at a dinner the previous Wednesday were continued on a novel system of speech amplification. In place of the conventional loud speakers mounted on the walls, each table had a small "transistor" radio receiver. Speech into the microphone was broadcast to these individual receivers by a miniature radio transmitter, built by the Institute's Laboratories for Research and Development. The echoes normally produced by the conventional wall loud speakers were eliminated, and the audience reported good, clear reception.

The Stated Monthly Meeting of The Franklin Institute was held on May 18, 1955, in the Lecture Hall. The meeting was called to order at 8:15 P.M. Approximately 200 members and guests were present.

The President asked for additions, corrections, or changes to the Minutes of the April Stated Meeting which were printed in the May JOURNAL. There being none, they were, on motion duly made and seconded, approved as submitted.

The President presented to the meeting the Annual Report of the Board of Managers for the year 1954. He summarized the report and announced that it would be printed in full in the July issue of the JOURNAL.

The President reported that the total membership as of April 30, 1955, was 6,895.

He then introduced the speaker of the evening, Mr. Charles S. Leopold, Consulting Engineer. Mr. Leopold, a Fellow and past President of the American Society of Refrigerating Engineers, was the 1954 recipient of the F. Paul Anderson Medal of the American Society of Heating and Air Conditioning Engineers. Among the other buildings for which he designed and supervised the installation of heating and air conditioning are the Pentagon and the United States Capitol in Washington, Madison Square Garden and the New York Stock Exchange, Convention Hall and the Packard Building in Philadelphia. His subject was "Controlled Indoor Weather for the Fidelity-Philadelphia Trust Building," and he discussed generally the objectives and problems of air conditioning and described the recently-completed installation in Philadelphia's largest office structure.

The meeting adjourned at 9:45 P.M. with a rising vote of thanks to Mr. Leopold.

HENRY B. ALLEN
Secretary

COMMITTEE ON SCIENCE AND THE ARTS

(Abstract of Proceedings of Stated Meeting held Wednesday, May 11, 1955.)

HALL OF THE COMMITTEE,
PHILADELPHIA, MAY 11, 1955.

MR. RALPH S. MCCLARREN in the Chair.

The following reports were presented for final action:

No. 3267: Work of F. P. Bowden.

This report recommended the award of an Elliott Cresson Medal to F. P. Bowden, of Cambridge, England, "For his extensive experimental investigations of the friction between solid surfaces, investigations which combine simplicity and clarity, and for his findings regarding the detailed nature of the processes involved when one metal slides over another."

No. 3287: Levy Medal.

This report recommended the award of the Louis E. Levy Medal to David Albert Huffman, of Cambridge, Massachusetts, "In recognition of his outstanding paper 'The Synthesis of Sequential Switching Circuits,' appearing in the March and April, 1954, issues of the JOURNAL OF THE FRANKLIN INSTITUTE."

JOHN FRAZER,
Secretary to Committee

MEMBERSHIP

ACTIVE MEMBERS ELECTED BY THE BOARD OF MANAGERS

May 18, 1955

ACTIVE FAMILY

Richard S. Cross
William E. Ehrich
Earl R. Miller
Boies Penrose
J. N. Pew III
Arthur A. Squier
Albert C. Strobel
Samuel Weisberg

ACTIVE

William G. Batt
Fedele V. Capozzi
David Young Cooper
Charles E. DeLong
Edward J. Doering
Clark Doran
Donald C. Furlong
Joseph Haines, Jr.
Henry L. Hollingsworth
John Franklin Huber
Thomas F. Irwin
Andrew L. Lewis
D. Rice Longaker
William B. Murphy
William N. Parkinson
Stanley Patterson
Noel Rippey
George A. Roberts
Edward R. Sanders
Luther W. Shadle
John J. Shinners, Jr.
Morton Smith
Richard J. Speirs
Mrs. A. J. Stoner
S. Muir Stroh
W. F. Stroud
Edward M. Troisch
John T. Verbeck
Edwin H. White
Harry G. Willard
Chris R. Wogan

NECROLOGY

W. E. Bowler '42
Gerald W. Caner '44
A. P. Godsho '36
John B. Klumpp '09
Charles H. Masland '18
George E. Shafer '44
F. P. Streeper '43
John B. Whitehead '53

LIBRARY

The Committee on Library desires to add to the collections any technical works that members may wish to contribute. Contributions will be gratefully acknowledged and placed in the Library. Duplicates received will be transferred to other libraries as gifts of the donor. 324 items have been added this month.

Photostat service. Photostat prints of any material in the collections can be supplied on request.

The Library and reading room are open from 9 A.M. until 5 P.M. on Mondays, Tuesdays, Thursdays, and Fridays; 2 P. M. until 10 P. M. on Wednesdays; and 9 A. M. until 12:00 NOON on Saturdays.

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JOURNAL OF THE FRANKLIN INSTITUTE

The following papers will appear in this JOURNAL within the next few months:

BENSON, EZRA TAFT: American Agriculture—A Great Past, A Greater Future
EPSTEIN, BENJAMIN: A Sequential Two Sample Life Test
MOON, PARRY AND DOMINA EBERLE SPENCER: On the Specification of Bôcher Equations
BURKS, ARTHUR W., ROBERT MCNAUGHTON, CARL H. POLLMAR, DON W. WARREN AND JESSE B. WRIGHT: The Folded Tree
MILLER, BERNARD L. AND W. C. PORTER: Secondary Electron Emission by Primary Electrons in the Energy Range of 20 Kilovolts to 1.3 Mev.
KLEIN, BERTRAM: Certain Aspects of Efficient Structural Design

NOTES FROM THE FRANKLIN INSTITUTE MUSEUM

A. C. CARLTON, DIRECTOR

CALCULATION MADE EASY

Before the calculating mind arrived at the present elaborate electronic computing instrument it had been at work for a very long time on efforts to simplify mathematical calculations. Many diverse methods were tried and served their day. Some of them, like the knotted cords used by the Aztecs, seem to have been so difficult to operate that the common way of figuring out a problem with the aid of pencil and paper has its advantages.

Starting out with a few pebbles (*calculi*, hence calculation) at first used loosely, the first mechanical calculating device was contrived by laying the pebbles on ruled slabs or boards and, later, by stringing them on wires where they served as "counters," constituting the abacus. This instrument was probably invented by the Semitic races, who were great traders and had need of quick reckoning, and who passed it to India, where it was adopted in very early days. From here it spread westward to Europe and eastward to China and Japan, where it is known as the Souanpan, anglicized to Swan-pan.

Although the abacus with its colored beads on wires never got very far from the nursery in western civilization, it passed into general use among the tradespeople of China and Japan, who became expert in its use. Meanwhile, in the west, other devices were being tried. John Napier invented numbering rods, known as "Napier's Bones," and Blaise Pascal made a calculating machine capable of addition and subtraction in the early years of the seventeenth century. Thereafter were many attempts by mathematicians and mechanists to develop a satisfactory machine that could be made commercially.

The same John Napier who had invented the "Bones" also invented logarithms. Then Edmund Gunter plotted logarithms on a two-foot line and added other lines for special purposes. Eventually, he placed these lines on a two-foot rule so that multiplication and division could be performed by the addition and subtraction of lengths by means of a pair of dividers. The slide rule finally emerged when William Oughtred, in 1621, used two Gunter scales sliding by each other so as to do away with the need for dividers. Both straight and circular forms were made. Numerous improvements were made, but the definite improvement in accuracy and graduation was due to the initiative of James Watt who, about 1779, introduced the slide rule into his Soho Works in connection with calculations in the design of steam engines. This rule was especially designed for the use of engineers and was known as the "Soho Rule."

Slide rules were constructed of boxwood, occasionally of brass or ivory, and it was not until 1886 that scales on celluloid were introduced, which gave a much greater distinctness to reading the figures. This material is now almost universally used.

The uninitiated observer is always deeply impressed at the manner in which a slide rule can be operated in skilled hands, and is envious of the ability to produce quick and accurate results without any mental effort. At length a new tool, less formidable in appearance and less mysterious in operation, has been prepared for general use. With the aid of this new tool complex calculations can be performed in a fraction of the time required by longhand methods.

The Museum has recently placed on exhibition charts which are virtually slide rules reduced to a plane surface. These charts are the gift of their inventor, Mr. Emmanuel J. George, of Philadelphia. As a chemistry instructor and engineer, Mr. George had perceived the need for a simple, quick, and inexpensive calculator. After experimenting with several approaches he hit upon the idea of superimposing a logarithmic scale diagonally on a logarithmic grid, from which it is possible to multiply and divide, as well as to obtain the logarithm, square root, or cube root of any number. No calculating is required. To obtain the solution to a problem of this kind, the user has only to glance at the chart, seek the intersection of two lines, and at that point read the answer.

Visitors to the Museum will find these charts on display in the Hall of Honor (adjoining Franklin Hall) on the First Floor, where a selection of examples of their use has been prepared. Copies of the charts may be purchased at the Book counter in the Planetarium Lobby.

NOTES FROM THE BIOCHEMICAL RESEARCH FOUNDATION

ELLICE McDONALD, FOUNDER
WILLIAM G. BATT, ACTING DIRECTOR

PHOSPHORYLATION OF 2-DEOXY-D-GLUCOSE BY YEAST HEXOKINASE: COMPETITION BETWEEN 2-DEOXY-D-GLUCOSE AND GLUCOSE

BY

GLADYS E. WOODWARD AND MARIE T. HUDSON

Although 2-deoxy-D-glucose (2DG) has been shown (1) to inhibit competitively the fermentation of glucose by intact yeast cells, proof was not obtained as to which enzymatic step in the fermentation system was the actual site of the inhibition. From the observation that the inhibitory effect of 2DG was very much less in a cell-free yeast extract than in the intact cell, it appeared that 2DG might be directly affecting an enzyme in the cell wall which was responsible for transfer of glucose into the cell. On the other hand, since 2DG as well as glucose was found to be phosphorylated by yeast hexokinase, the enzyme generally considered to initiate fermentation, there was the possibility that 2DG might be competing with glucose at this stage. In the present study this latter possibility has been investigated.

The rates of phosphorylation of 2DG, glucose and fructose by a purified yeast hexokinase have been measured. From these rates, the Michaelis dissociation constants (K_m) for the enzyme-sugar complexes have been calculated. Since the K_m for 2DG with hexokinase was found to be greater than that for glucose with hexokinase, there was indication that 2DG would not be very effective in preventing the phosphorylation of glucose by hexokinase.

Up to the present time, it had not been possible to measure the utilization of 2DG and glucose together in a reaction mixture, due to the inadequacy of analytical methods for determining each sugar in the presence of the other. Methods, based on the separation of the two sugars by paper chromatography, have now been worked out and applied to the study of the mutual inhibition of 2DG and glucose phosphorylation. This study shows that in an equimolar mixture of 2DG and glucose, the picture is in favor of glucose, rather than 2DG, as the inhibitor: the phosphorylation of glucose was inhibited but slightly, that of 2DG on the other hand was inhibited almost completely.

On the basis of these results it would appear that the inhibitory effect of 2DG in fermentation by intact yeast cells is not due to a simple competition between 2DG and glucose for hexokinase. However, it must be borne in mind that, in the present experiments with the

isolated enzyme, an excess of adenosinetriphosphate (ATP) was always added. In the intact yeast cell, the amount of ATP is relatively small, and even a slight reduction in the amount of ATP as a result of its utilization by 2DG might be sufficient to inhibit the fermentation of glucose. Further studies are needed for complete clarification of the mechanism by which yeast fermentation is inhibited by 2DG.

DETERMINATION OF THE MICHAELIS DISSOCIATION CONSTANT

The rate of phosphorylation of sugar was measured in the Warburg manometric apparatus at 30° C. by the method of Colowick and Kalckar (2), in which the liberation of one acid equivalent by the transfer of one phosphate group from ATP to sugar results in the liberation of one equivalent of CO_2 from bicarbonate in the medium. The reaction mixture contained 0.2 mg. purified yeast hexokinase (Pabst), 0.01 M ATP (pH 7.5), 0.01 M $MgCl_2$, 0.02 M $NaHCO_3$ and substrate as desired, the total volume being 2 ml. The hexokinase and substrate were placed together in the side arm of the flask and, after gassing with 5 per cent CO_2 in N_2, were tipped into the other materials in the main part of the flask. Readings were taken every 2 minutes for the first 10 minutes and every 5 minutes thereafter. In agreement with Berger *et al.* (3), the rate was linear for only about 8 minutes in most cases. The reaction rate was calculated from this initial linear portion of the curve.

When concentrations of substrate ranging from 0.0005 M to 0.005 M were used, the initial reaction rate for 2DG, glucose and fructose varied as indicated in Table I. Each rate figure represents an average

TABLE I.—*Reaction Rate of 2DG, Glucose and Fructose with Yeast Hexokinase.*

Concentration of sugar M	Initial Reaction Rate 2DG μl. CO_2/5 min.	Glucose μl. CO_2/5 min.	Fructose μl. CO_2/5 min.
0.0005	8.2	9.4	7.0
0.001	11.9	11.6	9.3
0.002	12.7	11.4	13.3
0.005	15.4	12.4	17.1

as determined from 3 experiments. From a plot of the reciprocal of the rate versus the reciprocal of the substrate concentration, the maximal reaction rate and the substrate-enzyme dissociation constant (K_m) for each of the 3 sugars were calculated according to the method of Lineweaver and Burk (4). The maximal rate of phosphorylation of 2DG was greater than that of glucose but less than that of fructose. The relative maximal rates of phosphorylation of glucose, 2DG and fructose were 1.0:1.3:1.6. K_m in terms of molarity was found to be 5.5×10^{-4} for 2DG, 1.8×10^{-4} for glucose and 1.1×10^{-3} for fructose. The K_m values for glucose and fructose are in fair agreement with those obtained by Slein, Cori and Cori (5) by other methods. The relative

order of affinity (reciprocal of K_m) of these 3 sugars for yeast hexokinase is the same as has been observed for the hexokinases of brain (6) or of Arbacia eggs (7), namely, glucose > 2DG > fructose.

DETERMINATION OF THE MUTUAL EFFECT OF 2DG AND GLUCOSE ON THE HEXOKINASE REACTION

The inhibitory effect of 2DG or glucose on the phosphorylation of each other could not be determined by the manometric method since both sugars contribute to the product measured. Analysis for the amount of 2DG or glucose remaining unreacted was the method adopted.

Four reaction mixtures were made up containing, in a total volume of 5 ml., 0.01 M ATP (pH 7.5), 0.01 M $MgCl_2$, 0.01 M tris(hydroxymethyl) aminomethane buffer (pH 7.5), 0.1 mg. purified yeast hexokinase (Pabst) and either 1) 0.01 M 2DG, or 2) 0.01 M glucose, or 3) 0.01 M 2DG plus 0.01 M glucose, or 4) no substrate. The hexokinase was added last to each mixture previously placed in a water bath at 30° C. After 15, 30, 45 and 60 minutes of incubation, 1 ml. of each mixture was removed and deproteinized by the Somogyi reagents (8), 1 ml. of both $ZnSO_4$ and $Ba(OH)_2$ being added. Control experiments showed that this treatment removed the hexose monophosphates which if present would interfere in a free sugar determination.

Since glucose and 2DG when present together interfere with each other in analytical methods, a chromatographic separation in the deproteinized filtrate from reaction mixture No. 3 was made before applying the analytical methods. Aliquot portions of 0.1 ml. of the deproteinized filtrates from reaction mixture No. 3 (equivalent to 120μg. of glucose and 109μg. of 2DG at zero time) were placed as 2 inch streaks, 2 inches apart, on the base line of Whatman No. 1 filter paper and separated by the ascending method (9) with water-saturated *n*-butanol as the solvent. The chromatograms were allowed to develop 4 hours, during which time the solvent ascent was about 7 inches. In order to serve as a guide for locating the areas which contained 2DG and glucose on the paper, one chromatogram was made in duplicate. After development of the chromatograms and air drying, the duplicate was cut away from other chromatograms and sprayed with Partridge's aniline phthalate reagent (10) which gave a color with 2DG similar to that with glucose. Although R_f values were not determined, 2DG was observed to have moved further up the paper than glucose and to be clearly separated from the glucose. As determined from the sprayed chromatogram, the other chromatograms were cut into 2DG and glucose strips. One end of each strip was tapered to a point and the other end was supported from a glass rod with two stainless steel clips, exposing the center of the edge of the strip. A dropping funnel containing distilled water was supported above with the tip (previously drawn out to a fine tip) just touching the center of the top edge of the paper.

2DG and glucose were then eluted from their respective strips by dripping water down them at the rate of 1 drop every 6 to 8 seconds until a total of 5 ml. of eluate was collected. Controls with known amounts of 2DG and glucose showed quantitative recovery of the sugars by this method.

Analysis for glucose was carried out by the Hagedorn and Jensen method (11), and analysis for 2DG by the quinaldine method of Cramer and Neville (12). All of the eluate from the glucose strips and 2.5 ml. of that from the 2DG strips were used for an analysis. Corresponding portions of the deproteinized filtrates from the other 3 reaction mixtures were analyzed directly for 2DG and glucose without being subjected to chromatography.

The amounts of 2DG and glucose found in equal samples of the 4 reaction mixtures at stated periods of incubation are given in Table II.

TABLE II.—*Mutual Inhibitory Effect of 2DG and Glucose in Phosphorylation by Yeast Hexokinase.*

Time of reaction	Sugar Remaining Unphosphorylated			
	Glucose alone	Glucose in presence of 2DG	2DG alone	2DG in presence of glucose
min.	μg.	μg.	μg.	μg.
0	120	120	109	109
15	106	107	84	112
30	93	96	75	104
45	79	83	61	104
60	75	80	48	96

It is apparent that the rate of disappearance of glucose was almost as fast in the presence of 2DG as in its absence. The rate of disappearance of 2DG alone was greater than that for glucose alone, but in the presence of glucose, 2DG disappearance was so slight as to be practically undetectable. Therefore, under the conditions of this experiment, the phosphorylation of glucose by hexokinase was only slightly inhibited by 2DG, whereas the phosphorylation of 2DG was almost completely inhibited by glucose.

SUMMARY

The relative maximal rates of phosphorylation of 2-deoxy-D-glucose (2DG), glucose, and fructose by a purified yeast hexokinase have been found to be 1.3, 1.0 and 1.6. The Michaelis substrate-enzyme dissociation constant for 2DG was determined to be 5.5×10^{-4} M. Comparison of this value to constants similarly determined for glucose and fructose showed that the affinity of 2DG for yeast hexokinase was about one-third the affinity of glucose but about twice the affinity of fructose. In an equimolar mixture of 2DG and glucose in which these sugars compete as substrate for hexokinase, the phosphorylation of 2DG was found to be almost completely inhibited by glucose, while the phosphorylation of glucose was but slightly inhibited by 2DG.

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NOTES FROM THE BARTOL RESEARCH FOUNDATION

RADIATIONS FROM PLATINUM (197) *

BY

V. R. POTNIS,** C. E. MANDEVILLE AND JOHN S. BURLEW ***

The radiations of Pt^{197} have been examined with coincident spectrometers of NaI-Tl and anthracene. Gamma rays have been detected at 77, 191, and 279 Kev, the unconverted quantum radiations having relative intensities of 30, 3.9, and 1.0. Coincidence measurements revealed the presence of three beta spectra of maximum energies 670, 479, and 468 Kev, terminating at levels in Au^{197} at 77, 268, and 279 Kev which are also excited (1,2) in the decay of Hg^{197} and by coulomb excitation (3). These beta spectra have intensities in order of decreasing end-point energy of 90.6, 8.4, and 1.0 per cent. These estimates are based upon the observed gamma-ray intensities and upon previously determined conversion coefficients, experimental (1,2) and theoretical (4). In the same order, values of log ft are 6.4, 6.88, and 7.8.

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ELECTRICAL CONDUCTIVITY INDUCED IN MgO CRYSTALS BY 1.3 MEV ELECTRON BOMBARDMENT *[1]

BY

M. A. POMERANTZ, J. F. MARSHALL AND R. A. SHATAS

Currents induced by the passage of a pulsed beam of essentially monoenergetic electrons through thin single crystals of MgO have been observed. Space-charge effects are eliminated by reversing the polarity of the potential across the crystal between successive 1 μsec pulses

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* Assisted by the Office of Ordnance Research, U. S. Army.

[1] Abstract of a paper presented at the Fifteenth Annual Conference on Physical Electronics, Massachusetts Institute of Technology, March 25, 1955.

which are observed oscillographically. The bombardment-induced current is proportional to the primary current and to the applied voltage in accordance with theoretical expectation.

The bombardment-induced current per unit primary current, $m \equiv I_e/I_p$, is given by

$$m = \delta v E \tau', \tag{1}$$

where δ is the number of internal secondary electrons raised into the conduction band by one primary electron per cm of path, v is the average mobility of the carriers, E is the electric field in the crystal, and τ' is the lifetime of the carriers before trapping. These measurements indicate that the value of τ' is approximately 3×10^{-11} sec.

The temperature-variation of the bombardment-induced conductivity has been measured over the range $-72°$ C. to 350° C., and the data can be represented by the relationship:

$$m = \frac{1}{A + Be^{-\alpha/T}}. \tag{2}$$

When the crystal is heated slightly above room temperature, conductivity persists after the termination of bombardment by the high energy beam. At 70° C. to 90° C., the post-bombardment conductivity decays in accordance with the empirical law:

$$I_e = \frac{C}{(D + t)^n} \tag{3}$$

where t is time after bombardment, and n is an exponent which changes with temperature.

At higher temperatures, the post-bombardment conductivity may be observed oscillographically. Although at 287° C. there is no indication of a tail on a 10 μsec time scale, at 348° C., a current is observed to persist after the termination of the primary pulse. At 421° C., the shape of the pulse during bombardment shows structure. The data obtained photographically follow the exponential decay law:

$$I_e = I_0 e^{-t/\tau}. \tag{4}$$

On the basis of a theoretical model which accounts quite satisfactorily for the observations, the time constant, τ, is expected to vary with temperature, as follows:

$$\tau = \tau_0 e^{E/kT}. \tag{5}$$

Points for which this time-constant is as long as 60,000 sec actually fall on the extrapolation of the line plotted over the range 10^{-4} to 10^{-5} sec., confirming the validity of the theory. The slope corresponds to a trap-depth of 1.4 ev.

THE OPTICAL ABSORPTION SPECTRA OF THORIUM OXIDE *

BY

J. H. BODINE AND F. B. THIESS

Absorption measurements in the region of 2200 Å to 10,000 Å were made on optically polished thoria crystals of 99.9 per cent purity. Firing the crystals in air and in vacuum at different temperatures gave the red, white and yellow forms described by Weinreich and Danforth.[1] The present improved instrumentation gave a cut-off at 3550 Å for all forms.

Vacuum firing at high temperature (1500°) gives a yellowish form. The white form is produced by lower temperatures and/or short times. Results will be reported regarding the progressive change from white to yellow forms as the temperature and time of firing are increased. Thin films prepared by oxidizing films of metallic thorium show rapid increase of absorption at 3550 Å.

Since the white state of thoria shows no absorption band, it seems to be the stoichiometric form of thorium oxide, with an optical intrinsic gap at 3.5 ev. The change to the red form seems attributable to thorium vacancies, since the oxygen ion is apparently too large to enter into interstitial sites. The absorption band at 4050 Å (3.0) ev. in the yellow crystals is presumably due to oxygen vacancies or to interstitial thorium.

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* Assisted by the Office of Ordnance Research.

[1] "Advances in Electronics," Vol. V, p. 203, 1953.

BOOK REVIEWS

ELEMENTS OF POWER SYSTEM ANALYSIS, by W. D. Stevenson, Jr. 370 pages, diagrams, 16 × 24 cm. New York, McGraw-Hill Book Co., Inc., 1955. Price, $7.50.

Power system planning engineers of today are faced with the problem of doubling the existing facilities of generation and transmission every ten years. This, when coupled with the problems of integral, interconnected operation with neighboring large systems, presents problems in engineering and economic analysis that defy exact mathematical solution.

However, to approach such problems in a logical and orderly manner, the engineer must have a solid background in the elements of power system analysis; and this text supplies just such a foundation.

Unlike many books covering this general subject, this one attempts to describe the more practical aspects of system analysis in addition to providing the underlying fundamental theory.

The author first develops the methods of calculating the various transmission line parameters and then explains the use of published tables of line and cable characteristics with several practical examples. This is followed logically with a classical treatment of long line theory and an introduction to hyperbolic functions.

It is at this point the author inserts a chapter on generalized circuit constants. This subject of ABCD constants is not found in the usual text and yet the method can be valuable to the power system engineer. These constants are further used in the following chapter on the construction and application of circle diagrams.

An excellent treatment is given the one line representation of power systems and includes an introduction to the invaluable system of per-unit notation. General use of this method of computation by the engineer merits a complete treatment of this subject by any text intended for engineering students.

Having provided a thorough background for general circuit analysis, the author introduces the subject of short circuit calculations. This topic naturally involves a development of the method of symmetrical components and calculations of sequence impedances.

The final section of the text is devoted to a discussion of power system stability with demonstrations of the mathematical solution and the use of the calculating board to determine machine swing curves.

This text, suitable for senior students in electrical engineering, also should prove an excellent reference for the practicing engineer as the author has included much of the more practical aspects of power system analysis.

W. A. HOPKINS

TITANIUM IN IRON AND STEEL, by George F. Comstock. 294 pages, illustrations, 16 × 24 cm. New York, John Wiley & Sons, Inc., 1955. Price, $6.00.

Titanium and its alloys have received considerable attention in recent years. This has resulted in a vast number of new publications concerning its uses, properties, preparation, etc. However, it is surprising to find that its use as a minor alloying element in steel has assumed such an important position. The present comprehensive summary provides us with the reasons why and makes us realize that titanium will become even more extensively utilized in the future.

The introduction presents a condensed discussion of the sources, preparation and properties of titanium and some of its alloys. This is followed by a chapter on the use of titanium as a deoxidizer in rimmed and killed steels. It is worthwhile to note that titanium is important as an addition to steel primarily because of its use in forming compounds with non-metallics in steel such as oxygen, sulfur, nitrogen and carbon. For this reason, about one-third of the book is devoted to the effects of titanium on those elements.

The effect of titanium in the various alloys of iron and steel is treated individually.

The alloys covered are cast steel, cast iron, pearlitic steels, low alloy steels and precipitation hardening steels.

Since a great variety of alloys are considered, the text is, of necessity, choppy. It is supplemented profusely by micrographs and graphs. The graphs are concerned mostly with the mechanical properties of the alloys as affected by titanium. Unfortunately in a great many cases, complete heat treating and grain size data are not given. This, however, is undoubtedly because such information was not given in the original reference.

There is a brief summary at the end of each chapter. The bibliography is at the end of the book and contains 282 references. There are both subject and name indexes. This reviewer did not note any errors in the text. This is not surprising, since the practice in the case of alloys of iron monographs is to have them reviewed by about thirty authorities on the subject before publication.

This volume certainly fulfills the purpose set up by The Engineering Foundation to supply the metallurgist, engineer and foundryman with complete up-to-date information on the effect of titanium on alloys of iron and steel. RAYMOND L. SMITH

THE EARTH AS A PLANET, The Solar System, Vol. II, edited by Gerard P. Kuiper. 749 pages, diagrams, 18 × 25 cm. Chicago, University of Chicago Press, 1954. Price, $12.50.

One of the most amazing facts concerning our universe is that we know more about the interior of the stars than we do the earth on which we live. The hydrogen bomb is testimony to our knowledge of the thermonuclear processes taking place deep inside the stars for the researches which culminated in the weapon had their origin in man's desire to comprehend the mechanism that kept the stars shining.

In the case of the earth the mathematical probes have, as yet, not been completely uncovered which, in turn, restricts man to very narrow limits in his exploration. Until recently the highest altitude attained by man was 14 miles. On the other extreme, the deepest mine is under 3 miles. Unmanned rockets have extended the 14 miles to 250 miles and water soundings have gone down 40,000 feet. These are the limits. For further information up or down extrapolation is necessary and this brings us to the book in hand.

The Earth as a Planet is the second of four volumes dedicated to the solar system and edited by Dr. Gerard P. Kuiper. It is a compendium of geoscience. In this book, in 15 chapters, the physics and chemistry of the earth and the physics of the atmosphere are summarized. It is the hope of the astronomer-editor that this work will prove valuable in guiding the astrophysical studies of the other planets. The earth is the only planet which the scientist can subject to close scrutiny. Interpretation of the fragmentary planetary data depends on our knowledge of the earth.

The dynamical properties of the earth are treated in Chapters I and II. In this the ranking men in the field are the authors. Sir Harold Spencer Jones, the Astronomer Royal, is eminently fitted for the task of reporting on the dimensions and rotation of the earth while Sir Harold Jeffreys reports on the dynamics of the earth-moon system.

Sir Edward Bullard discusses the interior of the earth as disclosed by the passage of seismic waves through it. The seismic waves are yielding a precise knowledge of the interior shells of the earth. Volcanic heat, radioactivity in the subsurface layers and the presence of a magnetic field are dealt with.

Chapter IV, by Dr. J. Tuzo Wilson deals with the development and structure of the crust. The distinction between ocean basins and continents is delineated and the evidence described which pictures the continents growing at the expense of the ocean basins.

Professor H. V. Sverdrup covers the oceans in Chapter V. The physics of the waters, the currents and the heat budget of the oceans are treated.

The geochemistry of the crust constitutes Chapter VI by Dr. Brian Mason.

Chapter VII deals with the atmosphere up to 30 kilometers by Professor Horace R. Byers while Dr. Fred L. Whipple discusses the atmosphere above 30 kilometers in Chapter X.

One of the most significant sections of the book is Chapter VIII by Dr. G. E. Hutchi-

son. This deals with the biochemistry of a terrestrial atmosphere. The literature abounds with allusions to the possibility of life on other worlds. The picture we project for planets other than the earth are in a large measure delineated by our knowledge of life in the earth's atmosphere. Dr. Hutchison closes his contribution by exploring the atmospheres of Venus and Mars for conditions suitable for life.

Dr. Leo Goldberg deals with the absorption spectrum of the atmosphere in Chapter IX while the emission spectra of twilight, night sky and the aurora are covered in Chapter XI by Drs. J. W. Chamberlain and A. B. Meinel.

D. R. Bates provides the Chapter XII, The Physics of the Upper Atmosphere. Here the mechanisms for the formation of the ionized layers, the air glow, the temperature and thermobalance are treated.

The Dynamic Effects in the High Atmosphere comprises Chapter XIII, by M. Nicolet. The motions in the high atmosphere are somewhat of a mystery, which is understandable when it is realized that problems of general circulation of the lower atmosphere has not been solved completely. M. Nicolet indicates the general dynamical problem requires much progress before quantitative explanations of the observations are possible.

The advent of the camera and television carrying high altitude rocket has made it possible to see the earth from outside the atmosphere. Clyde T. Holliday, who is in a large measure responsible for the successful photography, contributes Chapter XIV.

The last chapter by Andre Danjon on the Albedo, Color and Polarization of the earth completes the book.

The tremendous growth of the earth sciences has presented a challenge to the scientist in keeping his colleagues informed of the advances and current thinking. This book represents a complete reassessment of the advances and current trends by highly articulate authors who are most active in their particular fields.

The Earth as a Planet is a noteworthy contribution to the earth sciences and its editor, Dr. G. P. Kuiper, merits a "well-done" for his skill in bringing this to light.

I. M. LEVITT

NUCLEAR PHYSICS, by Alex E. S. Green. 535 pages, diagrams, 16 × 24 cm. New York, McGraw-Hill Book Co., Inc., 1955. Price, $9.00.

This volume of fourteen chapters presents a comprehensive discussion of all aspects of nuclear physics, including the most modern ones, with a thoroughness not usually encountered. Its content will be more fully appreciated by students who have previously experienced an introduction to theoretical physics such as is often given as an advanced undergraduate course. The approach to all topics is mathematical whenever possible, but physical concepts are not de-emphasized. Each chapter is concluded with problems designed to illustrate in more detail the preceding material.

The first chapter contains an extremely well organized review of atomic physics (the author has carefully distinguished between atomic physics and nuclear physics in the preface). Subsequent chapters culminate in exposition of the most recent nuclear theories. The last discussed nuclear model is the collective one. The experimental evidence relating to this particular model, e.g., electric excitation of the nucleus, is also mentioned.

At the end of each chapter is a comprehensive list of references which includes many of the most recent important papers. The eighth chapter deals with nuclear systematics as developed from analyses by the author.

C. E. MANDEVILLE

AUTOMATIC FEEDBACK CONTROL SYSTEM SYNTHESIS, by John G. Truxal. 675 pages, diagrams, 16 × 24 cm. New York, McGraw-Hill Book Co., Inc., 1955. Price, $12.50.

During and since World War II very notable advances have been made in many areas of scientific knowledge. New methods and tools have been discovered which have made inroads possible into heretofore relatively uncharted and difficult fields. The field of servomechanisms and feedback control for one has prospered greatly from the effort of the past years. The many technical advances, stimulated and made necessary by acute problems of fire control, guidance, etc. have actually opened up an entirely new era of automatic control. These

newly developed techniques have also created, however, a need on the part of designers and engineers for a familiarity with certain aspects of electrical engineering which are not second nature to the majority. To help meet this need, this book was written.

Several important and worthwhile texts have come forth touching on various aspects of this problem. Prof. Truxal's book is the first, in the knowledge of this reviewer, to offer such a complete treatise on most of the important techniques available to the designer of feedback control systems. The book contains 11 chapters, an attempt being made to make each self contained. Chapter 1 serves as an introduction and a review of the mathematical background. Chapters 2 and 3 cover the basic theory necessary to the fields of servomechanisms and network synthesis. Chapters 4, 5, and 6 describe the important aspects of design in terms of the Laplace transform. Statistical design theory is described in Chapters 7 and 8 while Chapter 9 presents the basic characteristics of sampled-data feedback systems. The text concludes with two chapters on the analysis of nonlinear feedback systems.

In his book, which has been more carefully and clearly written than most, Professor Truxal has attempted to teach the maximum utilization of all available design theory. An adequate number of examples are worked out to illustrate the theory and design techniques as they are introduced; and throughout the text, references are given to most of the basic papers dealing with the theory. It seems certain that this book will prove to be a valuable and often referred to reference on the book shelves of both practicing engineers and students who find themselves confronted with problems in this field. D. L. BIRX

GENERAL THEORY OF HIGH SPEED AERODYNAMICS, edited by W. R. Sears. 758 pages, illustrations, 16 × 24 cm. Princeton University Press, 1954. Price, $15.00.

This volume is number six of a series of twelve volumes on high-speed aerodynamics and jet propulsion treating in sequence elements of the properties of gases, liquids, and solids; combustion processes and chemical kinetics; fundamentals of gas dynamics; viscous phenomena; turbulence; heat transfer; general theory of high-speed aerodynamics; applications to wings, bodies and complete aircraft; non-steady aerodynamics; principles of physical measurements; experimental methods in high-speed aerodynamics and combustion; aerodynamic problems of turbomachines; the combination of aerodynamic and combustion principles in combustor design; and problems of complete power plants. The intent of the series is stated to be, "—to emphasize the fundamental aspects of jet propulsion and high-speed aerodynamics, to develop the theoretical tools for attack on these problems, and to seek to high light the directions in which research may be potentially most fruitful."

This volume consists of eight major sections, each of which is authored by experts in their particular field. The editor is to be congratulated on having molded and coordinated the wide variety of topics, some of them presented for the first time, in such a comprehensive manner. The fast-moving and increasingly complex field of high-speed flow has created many gaps in the background of knowledge required by the vast groups of aerodynamic specialists, students and teachers alike. Accordingly, the unified and authoritative presentation of the material in this volume should be of fundamental and practical value; a welcome addition to the library of aeronautical sciences.

In the first of the eight sections, von Kármán discusses the essential physical concepts of the entire field; a sort of foundation followed by more detailed treatment in subsequent sections. Friedrichs takes account of the general mathematical structure of flow problems of hyperbolic type in the second section. In the third section Editor Sears presents the simplification of the mathematical problems of compressible fluid flow by the theory of small perturbation approximations, exploiting them principally in subsonic flow situations. Small perturbation theory is extended beyond the subsonic regime in the fourth section (by far the most extensive of this volume) entitled "Supersonic and Transonic Small Perturbation Theory," by Heaslet and Lomax; eight sub-divided chapters deal with the wave equation and methods of solution, two-

dimensional supersonic steady state flow, three-dimensional supersonic steady state flow, axially symmetric supersonic steady state flow, slender airplane theory, unsteady lift, reciprocity relations and reverse flow theorems, and small perturbation theories of transonic and hypersonic flows.

Lighthill in the fifth section, Higher Approximations, describes and reconsiders certain cases by taking into account their nonlinear effects—a sort of critique of the process of linearizing problems of adiabatic flow. The subject of the sixth section by Kuo and Sears, plane subsonic and transonic flows, treats the exact solution of the two-dimensional subsonic and transonic case of steady plane flow by the hodograph method, i.e., the use of velocity components as independent variables.

The method of characteristics and supersonic flows with shock waves are the subjects of the last two sections (G and H) by Ferri. In section G, the physical and mathematical results of the first two sections are used with the purpose of obtaining methods of analysis of supersonic flow fields related to practical aerodynamics. The last section, dealing with the relation between boundary conditions and shape of the shock waves in a steady flow field, treats a variety of problems in transonic and supersonic flows, some of which are similar to those presented previously by Lighthill and Heaslet and Lomax, but with a refreshingly different approach.

The publishers are to be congratulated on the general excellence of the volume. It has been selected as one of the "Fifty Books of the Year" by the American Institute of Graphic Arts—the first time an advanced technical book has been so honored.

S. M. BERKOWITZ

INSTRUMENTAL METHODS OF ANALYSIS, by Galen W. Ewing. 434 pages, diagrams, 16 × 24 cm. New York, McGraw-Hill Book Co., Inc., 1954. Price, $6.50.

In the infancy of chemical analysis, identification of chemical composition was totally carried out by the wet method techniques of solution, separation and assay. However with the advent of the spectroscope late in the nineteenth century, an entirely new approach to analysis was initiated. New instrumental methods of analysis dependent on the inherent physical properties of the components in question are constantly appearing in the literature. The increased knowledge of electronics has given rise to not only new but extremely precise instruments. Now the physical properties found applicable to chemical analysis are very extensive and can roughly be grouped in six general classifications: extensive properties; mechanical properties; properties involving interaction with radiant energy; electrical properties; thermal properties; and nuclear properties. This book discusses accepted methods in these classifications, but it does not presume to discuss those methods which are barely out of the research stage.

The text was written for the purpose of presenting to the senior undergraduate and first year graduate chemistry student an over-all source of instrumental analysis without a working or even passing knowledge of physical chemistry. The author has accomplished this in his simple approach to the subject with a minimum emphasis on mathematical background and his very well organized chapters on laboratory experiments; however, the text is necessarily limited by his primary purpose.

The text is composed of twenty-one chapters on Principles, thirty-three chapters on Laboratory Experiments, and five appendices. Each chapter considers its subject thoroughly presenting modifications, limitations and possibilities. It is well illustrated and the illustrations are concisely and clearly described. The appendices are not very extensive.

PHYLLIS A. PARKIN

BENJAMIN FRANKLIN: THE FIRST MR. AMERICAN, by Roger Burlingame. 122 pp., New York, New American Library of World Literature, Inc., 1955. Price, $0.25.

Roger Burlingame's little biography of Benjamin Franklin is especially timely in that the 250th anniversary of his birth is to receive world-wide observance next year. Carl Van Doren, the eminent historian and Franklin biographer, told me once that next to the Bible, Franklin's Autobiography has had the largest circulation, over the world, than any other writing. Since Franklin's

death many biographies have been written; but rarely does one find one that gives the true, balanced, and entertaining picture of that unique citizen of America, and of the world, as does Mr. Burlingame's—and all in slightly more than a hundred pages of a pocket-size book. No matter how thoroughly acquainted one is with Franklin's life and writings, this little book can be read with profit and pleasure.

H. B. ALLEN

QUANTITATIVE ANALYSIS, by A. F. Daggett and W. B. Meldrum. 470 pages, diagrams, 16 × 24 cm. Boston, D. C. Heath and Company, 1955. Price, $5.00.

The authors of the text have proposed to give meaning to the "rule-of-thumb" approach to quantitative analysis. By attempting to define certain simple physical background, they have given reason for possible errors. I, for one, must admire any attempt to rescue quantitative chemistry classical techniques from what I prefer to call "cookbook" chemistry. Any thinking person, no matter how limited his present knowledge may be, will object to the automaton execution of analytical procedures.

The text is well organized. The primary analytical tool, the balance, is given much consideration. The authors also devote considerable space to the "sterile" approach of the analyst, since contamination is his foremost enemy. The classical approach to gravimetric and volumetric analysis is basically much as similar texts with the additional approach of "why." Of particular note is the chapter on Electrolytic Principles. This is a very useful tool in analysis with a reasonably direct procedure. Also in this chapter, electro-separation is also briefly discussed.

The text is composed of sixteen chapters on Principles, twenty-five chapters on Laboratory Experiments (much more extensive than the usual text of this type) and eight useful appendices.

The authors in their Laboratory Experiments repeat some of the why and wherefore of the procedure which they do not consider wasted space, for which I must commend them. PHYLLIS A. PARKIN

PHYSICS OF THE PLANET MARS, by Gerard de Vaucouleurs. 365 pages, diagrams, plates, 15 × 22 cm. New York, The Macmillan Co., 1955. Price, $10.00.

The mid-Twentieth Century Percival Lowell appears to be an obscure French astronomer who has rocketed to prominence because of his researches on the planet Mars.

Perhaps the most controversial subject in all of astronomy is the canals on Mars. Since they were first seen and sketched by Giovanni Schiaparelli in 1877 the canals have been a source of speculation. Percival Lowell built an observatory and contributed his private fortune trying to prove that these were, indeed, canals—wrought by an intelligence perhaps superior to our own. While he did not succeed in proving his point he did manage to focus the attention of a large segment of the astronomical fraternity on the red planet.

Today, when the entire arsenal of superbly manned astronomical instruments is waiting for perihelic opposition of 1956 to bear down on the problem, Dr. Gerard de Vaucouleurs, astronomer at the Observatoire du Houga, has introduced the second of his two books on Mars in 8 years. Like his first, this book is an English translation.

Whereas his first effort was a popular exposition on Mars, *Physics of the Planet Mars* is a mature, lucid, professional study which qualifies it as the last word in areology. The author confines himself to what is definitely known. He liberally spices his efforts with quotations from the researches in the field. As a result, the book, containing a systematic and detailed survey of the best available data, becomes a veritable mine of information in which the author properly assesses past researches in light of what is known today.

Physics of the Planet Mars comprises five sections. Part I deals with the all important Martian atmosphere. Here is detailed what is known of the chemical composition, pressures, clouds and atmospheric currents. Part II describes the climate on Mars both from the theoretical and observation analysis. Part III takes up the problem of the Polar Caps, their structure and composition. Here is covered the all-important question

of water on Mars. Part IV describes the bright and dark surface areas of the planet. The last section deals with the internal constitution of the planet.

The book ends with a significant summary of its five parts and the outline of a research program.

Physics of the Planet Mars is the most authoritative work on Mars and will persist as the ranking book on this subject for a long time. Its author has made his mark with this work and merits the congratulations of his colleagues in this field.

I. M. LEVITT

PRINCIPLES OF MACHINE DESIGN, by Samuel J. Berard, Everett O. Waters and Charles W. Phelps. 534 pages, illustrations, 16 × 24 cm. New York, The Ronald Press Co., 1955. Price, $7.50.

For the student who has completed courses in kinematics and strength of materials, *Principles of Machine Design* is a good introduction into the fundamentals of machine design. It is not an advanced book, but it will provide a sound background in the subject.

Following a brief description of the fundamentals of machine design, the authors (S. J. Berard, Brown University, E. O. Waters and C. W. Phelps, Yale University) discuss the engineering materials used in machine design. This is a very informative chapter. In a short concise way, the production and uses of such basic materials as cast, malleable and wrought iron, cast and alloy steel, copper and aluminum alloys, and natural and synthetic products are explained. The elements of theoretical design, being a brief review of mechanics and strength of materials pertinent to the subject, are not described.

These introductory subjects are then followed by the major part of the book. Part II describes screws, bolts, pins, keys and welding; Part III, shafting, couplings, clutches and bearings; Part IV, belt, chain and gear drives; and Part V, such mechanisms as cams, linkages, springs, brakes, curved beams. The basic principles involved in the design of each of the machine elements described are clearly shown by illustrative examples, so that one should have a sound understanding of the purpose of each. The authors mention that in the last few decades machine design has finally reached a welcome state of maturity in the sense that rational design has replaced guesswork. *Principles of Machine Design* demonstrates many of these new concepts of design.

E. W. HAMMER

ANNUAL REVIEW OF NUCLEAR SCIENCE, VOLUME 4, 1954. 483 pages, 15 × 23 cm. Stanford, Annual Reviews, Inc., 1954. Price: $7.00 (U. S.); $7.50 (foreign).

The fourth volume in this series is very much like its precursors. A wide spectrum of topics in nuclear science is covered: proton accelerators, photonuclear reactions, radio-frequency spectroscopy, radioactivity standardization, nuclear particle detection, alpha radioactivity, positronium, π-mesons, heavy mesons, penetration of heavy charged particles, biochemical effects, radiobiology, and radioactivity in geology.

The 17 articles by 25 authors differ widely in scope, treatment, length and significance. However, all are well written. The reviews vary from 12 pages and 15 references to 61 pages and 592 references. Some are complete surveys and give a historical development, experimental techniques and results and discuss theory. Some review only the last few years and are confined to only one aspect of a large subject. Some devote themselves to recording only experimental results; this seems to be the case in the articles on heavy mesons and vertebrate biology. The authors of these articles make it clear, however, that very little else is known in these fields. One may wonder if the editors need use this method to indicate our lack of knowledge.

One other subject seems to be given undue emphasis by being included. "Stable Isotope Dilution as an Analytical Tool" seems to be too narrow a field for use in these volumes. Most of the reviews do cover broad fields and do indicate broad outlines of a system in the facts we have in these fields.

On the whole, reviews such as these are extremely worth-while for they allow the interested scientist a chance to bring himself up-to-date with a relatively small investment of time and effort.

LEONARD MULDAWER

PUBLICATIONS RECEIVED

PLANE TRIGONOMETRY, by C. R. Wylie, Jr. 381 pages, diagrams, 16 × 24 cm. New York, McGraw-Hill Book Co., Inc., 1955. Price, $4.00.

FLIGHT HANDBOOK, edited by Maurice A. Smith. Fifth edition, 282 pages, plates, 15 × 22 cm. New York, Philosophical Library, 1955. Price, $6.00.

GENERAL CHEMISTRY, by L. E. Steiner and J. A. Campbell. 675 pages, diagrams, 16 × 24 cm. New York, The Macmillan Company, 1955. Price, $6.50.

WATER SUPPLY ENGINEERING, by Harold E. Babbitt and James J. Doland. Fifth edition, 608 pages, 16 × 24 cm. New York, McGraw-Hill Book Co., Inc., 1955. Price, $8.50.

THE TESTING AND INSPECTION OF ENGINEERING MATERIALS, by Harmer E. Davis, George Earl Troxell and Clement T. Wiskocil. Second edition, 431 pages, diagrams, 16 × 24 cm. New York, McGraw-Hill Book Co., Inc., 1955. Price, $6.50.

SCIENCE AND THE HUMAN IMAGINATION, by Mary B. Hesse. 171 pages, 15 × 22 cm. New York, Philosophical Library, 1955. Price, $3.75.

DOWN TO EARTH, by Robin Place. 173 pages, illustrations, 15 × 22 cm. New York, Philosophical Library, 1955. Price, $7.50.

TWO YEARS IN THE ANTARCTIC, by E. W. Kevin Walton. 194 pages, illustrations, 15 × 22 cm. New York, Philosophical Library, 1955. Price, $4.75.

POMP AND PESTILENCE, by Ronald Hare. 224 pages, 14 × 20 cm. New York, Philosophical Library, 1955. Price, $5.75.

FORBIDDEN LANDS, by Gordon Cooper. 165 pages, plates, 15 × 22 cm. New York, Philosophical Library, 1955. Price, $4.75.

THE ARMENIAN COMMUNITY, by Sarkis Atamian. 479 pages, plates, 15 × 22 cm. New York, Philosophical Library, 1955. Price, $4.75.

BABA OF KARO, by Mary Smith. 299 pages, 15 × 22 cm. New York, Philosophical Library, 1955. Price, $7.50.

TO MEMBERS AND THOSE WHO KNOW THE FRANKLIN INSTITUTE

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CURRENT TOPICS

"Over-the-Horizon" Transmission. —Direct television and multi-channel telephone transmission through space for as much as 200 miles—without relay stations and at ultra-high frequencies—has been accomplished, Bell Telephone Laboratories and the Massachusetts Institute of Techology have announced.

Television pictures, as well as radio and telephone conversations can be sent over the horizon on ultra-high frequencies, in an extension of a transmission technique recently applied to the continental defense system.

Principal virtue of over-the-horizon transmission is that longer communications bridges are possible over water and rugged terrain. In the present microwave radio relay network across the United States, relay stations are 30 miles apart.

Standard AM radio broadcasting employs waves that follow the earth's curvature. But waves used in television and telephone relays were presumed to travel in a straight line. For many years, "line-of-sight" transmission between antennas placed on towers on the horizon (about 30 miles apart) was thought to be the only practical means of transmitting by radio the wide bands needed for television and multi-channel telephone service.

This was disproved after years of research at M.I.T. and the Bell Telephone Laboratories. The Bell Laboratories' research stemmed from Bell's success with transcontinental microwave systems for carrying telephone conversations, radio and television programs from coast to coast and their continued interest in radio propagation. The M.I.T. interest was stimulated by work for the Government in radar and overseas broadcasting.

Scientists knew that ultra-high frequencies traveled over the horizon under certain conditions but believed them to be too weak and undependable for practical use.

In the course of investigating occasional interference attributed to these waves, however, the scientists discovered that many actually overshot the relay towers they were aimed at and arrived at farther points with remarkable consistency.

The next step was to provide reliable long distance transmission over-the-horizon. M.I.T. and Bell Laboratories' engineers did this by erecting larger antennas and using higher power than is employed in the conventional microwave system. Thus, they put to use the weaker signals that drop off a straight radio beam beyond the horizon and are reflected or scattered to distant points by the atmosphere.

The effect of the new system is very much like that of a powerful searchlight, which casts a beam in a straight line. A searchlight aimed at the sky can be seen from the ground miles away, even when the searchlight is behind a hill. This is possible because some of the light is reflected to the ground by the atmosphere.

In order to make use of over-the-horizon transmission, 10-kilowatt transmitters and 60-foot-diameter antennas are being used. This is 20,000 times the power and 30 times the an-

tenna area used in the present transcontinental microwave system. It was found necessary to employ the lower frequencies (in the UHF band) to develop with the available equipment sufficient power to attain a satisfactory degree of reliability.

Even after scientists learned that transmission was possible over-the-horizon, they were not certain that this medium would support the broad band of frequencies needed for multichannel telephone or television transmission. In the fall of 1953, they found that they could transmit 12 voice channels over the horizon.

Television was first successfully transmitted over the horizon in 1954 between the Holmdel, N. J. laboratory of the Bell Telephone Laboratories and the M.I.T. Round Hill Research Station near New Bedford, Mass., a distance of 188 miles.

Bell and M.I.T. scientists emphasize that this success with over-the-horizon transmission will probably result in a supplement to, rather than a replacement of line-of-sight radio relay systems.

Over-the-horizon signals are not to be confused with a similar type of transmission known as "ionospheric scatter," which is useful in long-distance transmission of telegraph signals at relatively low frequencies. Unlike ionospheric signals, the over-the-horizon technique provides signals that are useful for the wide bandwidths required for a television picture or by many telephone channels.

New Method for Mounting Diamonds.—Dr. H. Tracy Hall, one of the GE Research Laboratory team members responsible recently for the creation of man-made diamonds, has a novel method of mounting stones in diamond tools with crystal savings of up to 90 per cent. In a conventional mount, as much as 90 per cent of the diamond used may be buried in the tool in order to gain rigidity and prevent loss of the stone. Hall mounts, for example, a considerably smaller diamond in a shallow cavity on the surface of a single-point wheel-dressing tool. Formerly, a deep cavity would have been necessary.

One secret is the use of titanium hydride as a "wetting agent," and a solder, such as silver-copper. The parts are brazed by induction or radiation heating in a high-vacuum system, or in an atmosphere of very pure argon or hydrogen gas. In strength tests, a small diamond tip mounted on a microtone blade and revolved at 56,000 revolutions per minute, placed a force of about 50,000 pounds per square inch on the bonding area. However, this force was insufficient to dislodge the diamond.

Dr. Hall's process already shows great promise of industrial use. The advantages claimed are four-fold: (1) the diamond is more securely anchored to its mount; (2) the wasted "root," which in many cases is three-fourths of the volume of the entire tool point, can be eliminated; (3) much smaller diamonds can be mounted to provide the same working surface, effecting a substantial saving, since diamond prices rise steeply with increasing size; and (4) heat transfer is better when a diamond is bonded to metal than when there is only a mechanical connection, since a cooler working diamond will wear longer and is less likely to fracture from temperature shock.

Accurate "Ready-Mix" Standard Solution.—The modern use of prepared "ready-mixes" common to the housewife in her kitchen has been adapted to the industrial and scientific laboratory with the introduction of a newly developed ready-to-use standard

solution being placed on the market by the Chicago Apparatus Company, one of the nation's laboratory supply houses.

The new solutions, called "Stansols," bear the manufacturer's guarantee for accuracy within one part in 1000, and are standardized five times before packaging, according to J. O. Bengston, president of the Chicago company.

"For many years chemists and laboratory technicians have sometimes been reluctant to use standard solutions they had not prepared themselves," Bengston said. "The accuracy of 'Stansols' now permits their use with complete confidence."

Standard solutions are widely used in industrial and chemical laboratories as reference solutions for testing chemical formulas in research and control work. The solutions are standardized to a strength against which the comparison can be made.

Bengston listed these advantages of "Stansols":

1. *Accuracy.* Each batch is closely controlled by methods more accurate than usual laboratory procedures, and each is standardized five times before packaging.

2. *Economy.* Use of "Stansols" saves both time and money. Where preparation of such solutions in the laboratory would take from one hour (in standardizing against a secondary standard) to three days (against a primary standard), "Stansols" permit preparation of accurate volumetric solutions in a few minutes, and at much less cost.

3. *Packaging.* "Stansols" are put up in convenient, unbreakable polyethylene bottles in uniform size. A heat-sealed membrane under the screw cap eliminates spillage and atmospheric contamination.

4. *Convenience.* The polyethylene membrane is easily and cleanly opened with a special blade supplied with each bottle. The non-wetting properties of polyethylene facilitate transfer of the contents, and eliminate one source of error heretofore prevalent.

5. *Stability.* "Stansols" may be stored indefinitely without deterioration until opened and used. Chemicals which tend to be unstable in solution are supplied in crystalline form.

6. *Simple preparation.* A relatively unskilled laboratory technician can prepare and use "Stansols" whereas only trained personnel can prepare their own standard solutions.

The Chicago Apparatus Company is marketing "Stansols" in a wide variety of solutions, and Bengston said any type of solution for particular needs can be developed.

New Residue Cracking Process.—Houdry Process Corporation has disclosed a new catalytic cracking process that completely converts the bottom of the petroleum barrel into the most desirable refinery products and leaves no heavy residue. The process has been in successful commercial operation for a year at the Sun Oil Company's new refinery at Sarnia, Ontario, Canada. Proved efficient and profitable in this initial installation, it now becomes available under license to the refining industry generally.

Greater yields of high octane gasoline and domestic furnace oil, total conversion of heavy residue, and elimination of the production of heavy residual fuel oil are the characteristics that distinguish the new catalytic cracking process from others.

The new process draws its name—Houdresid—from its ability to convert the metal-contaminated residue of some conventional distillation operations into high quality products. This residue, having little value except in

asphalt or Number 6 heavy (bunker) fuel oil, has long been a troublesome problem for refiners.

The international market for heavy fuel oil has progressively softened in recent years as heavy fuel oil has become increasingly available abroad in Iran, Venezuela, and other countries.

Up to this time, no economically feasible catalytic cracking process for residuum has been available to refiners, although a few individual refining companies have done some catalytic cracking of residues from selected stocks.

Commercial operation of the Houdresid process at Sun Oil's Sarnia refinery has demonsrated that a way has been found to mitigate the effect of heavy metal contaminants on the catalyst. Heavy metal deposited on the catalyst in the Sun Houdresid cracker has had no significant effect on catalyst activity or selectivity.

Mechanical design of a Houdresid unit is based on equipment developed in the Houdriflow moving-bed catalytic process for cracking gas oil fractions of crude petroleum. Slightly higher equipment and operating costs for Houdresid processing are more than made up by higher value of products, and payout of incremental investment is accomplished in a few months.

Sun Oil has conducted Houdresid catalytic cracking since March, 1954, in which reduced crude representing 50 per cent "bottoms" from a mixture of Texas, Louisiana and Mid-Continent crudes is charged to the Houdresid unit.

Approximately 64 per cent gasoline is produced from the residuum, as compared to 52.5 per cent motor gasoline yield from conventional vacuum distillation plus catalytic cracking.

Blood Warmer Perfected for Infant Exchange-Transfusions.—A General Electric physicist who normally specializes in neutron spectrometry, magnetic materials and computers has been co-operating with physicians in an effort to help save the lives of babies born with the wrong type of blood.

He has invented a blood-warming device to lessen the shock which newborn Rh-negative infants endure when new, but cool, blood is substituted for the original deadly supply with which they are born. The basic operation—known to physicians as an "exchange transfusion"—is one of the newer miracles of modern medicine, developed by Harvard's Dr. Louis K. Diamond and others.

This operation has saved some 90 per cent of the babies formerly doomed to die within a few days of birth because of incompatible blood. The operation is usually accomplished by using whole blood from an acceptable donor, inserting a plastic tube in the baby's umbilical cord, and with a syringe (pump), and two three-way stopcocks, exchanging approximately 500 cc. of blood. However, this new blood is normally some 18 to 28 degrees below normal body temperature and is believed by some physicians to cause severe shock to an infant's system.

G. E.'s contribution is the direct outcome of an over-the-fence conversation one day, between Dr. Stewart C. Wagoner, Schenectady pediatrician, and Dr. Volney C. Wilson, physicist at the General Electric Research Laboratory. Wilson's youngest son, now 6, had been an Rh-negative baby, saved from probable death by just such an operation. Dr. Wagoner felt that it should be possible to save more than 90 per cent of these infants if some suitable way could be found to warm the blood, just as it enters the baby's body.

The first model of the G. E. blood warmer was a rather crude-looking

affair—a baked enamel kitchen pot holding a heating element and controls to raise the water temperature to the proper level, plus tubing, pump, stopcocks, and a small-bore stainless steel cylinder around which a water jacket was placed to serve as a heat exchanger.

The latest model is similar in operation but the water container is stainless steel, the heat exchanger has been redesigned, a single 4-way stopcock has been fashioned to take the place of a pair of 3-way valves, and other elements have been carefully engineered to take care of specific emergencies. During the past two years, the blood warmer has been used by Drs. Wagoner and Frank L. Marting in operations to save the lives of more than 20 endangered infants delivered at hospitals in Schenectady. Thus far they have had no fatalities when the blood warmer has been used, and no evidence of shock. Their initial technical report appears in a recent issue of the American Medical Association's *Journal of the Diseases of Children*.

18,000 Eggs a Week, but None Is for Breakfast.—A Detroit firm uses more than 18,000 eggs a week, but not even one is for breakfast. The large white fertile eggs are trucked in several time a week from wholesalers in Grand Rapids and Bancroft, Mich., to Parke, Davis & Company for the production of influenza vaccine.

Once received by the flu vaccine group, the eggs—all 18,000—go through ten different operations, which is equivalent to 180,000 eggs. They are first lifted from the cases into trays and put in the initial incubator for 11 days. From there, they are taken to a darkened area for candling, and the unfertile ones are eliminated.

Next, the eggs are taken to an air-conditioned room where they are painted with an antiseptic solution that turns yellow and gives them an Easter appearance. They are injected with influenza virus and put into a second incubator for two days. Then the eggs are recandled, unsatisfactory ones eliminated and the remainder refrigerated over night, after which the vaccine fluid is harvested. Then the eggs are destroyed.

Many further steps are required before the vaccine is ready for shipment, but the role of the egg ends with the fluid harvesting.

Because the production of flu vaccine is exacting, high standards have been set for what one might consider the lowly egg, Dr. Kenneth C. VanNocker said.

"The hens must undergo frequent inspection to be free of disease," he added. "The eggs must be nest cleaned with no contamination on the shell and show a high percentage of fertility."

The Parke-Davis research department requires a small quantity of eggs for testing and animal dietary requirements. Elsewhere in the company, approximately 2,000 more eggs are used in various departments.

The firm's purchasing department pointed out that the 20,000 eggs used weekly now are just a drop in the bucket compared with the total used during World War II. Because of the armed forces' demand for vaccine, the company then required approximately 125,000 eggs a week!

The people who handle the eggs at Parke-Davis still enjoy them for breakfast.

Electronic Tubes for Locomotives.—The first dual-powered American passenger locomotive equipped with electronic tubes for converting a-c. power to d-c. power has been deliv-

ered to the New York, New Haven and Hartford Railroad.

G. W. Wilson, General Manager of G. E.'s Locomotive and Car Equipment Department, said his Company is building ten of these highspeed passenger locomotives for operation over New Haven's electrified lines between New York City and New Haven. On this run, the new rectifier locomotives must operate on both alternating and direct current power systems.

On the a-c. system, the new locomotives receive 11,000-volt power from an overhead wire and, by means of electronic tubes in combination with a power transformer, change it into low-voltage direct current, much the same as that directly received by the locomotive from the third rail in the d-c. zone. This direct current is used to power traction motors on the locomotive's axles.

The tubes that transform the a-c. power to d-c. have a function similar to the small rectifier in an ordinary radio set. These tubes however measure 8 in. in diameter and weight more than 100 lb. each.

According to Mr. Wilson, rectifiers on locomotives and cars may revive interest in railway electrification for three major reasons: First, their ability to convert commercial frequency a-c. to d-c. power for traction motors opens up many new possible railway applications. Second, new rectifier materials give promise of smaller, more efficient power packages. Third, they allow the use of highly-developed, mass-produced diesel-electric locomotive components, thus reducing the first cost of motive power—an item that, thus far, has been an obstacle to further electrification.

In addition to operating on both a-c. and d-c. power on the New Haven to New York City run, the new locomotives must receive the power from two different distribution systems. While in the a-c. zone, the 11,000-volt, 25-cycle power is collected by a pantograph trolley on the roof that runs along an overhead wire. Although each locomotive has two pantograph trolleys, only one is normally used in service. The current flows from the trolley to the main transformer and then to the 12 main rectifier tubes. Power output from the rectifiers supplies six traction motors.

In the d-c. zone, power is supplied from a third rail at 600 volts. Here the locomotive collects the current through shoes on its trucks contacting the third rail.

All of the rectifier locomotive's 348,000 lb. are carried on its six axles. There are no extra wheels to spread the weight. Locomotives currently used in passenger service on the New Haven's electrified lines weigh 84,000 lb. more than the rectifiers, but carry 74,000 lb. less on the drivers, because they have a guiding truck with two axles on each end which distributes the weight.

In recent years, the direct-current traction motor has benefited from the development of the diesel-electric locomotive. Mass production plus experience gained from thousands of motors in service have greatly reduced the manufacturing cost and maintenance expense.

New Haven rectifier locomotives are equipped with General Electric's standard GE-752 motor which is also used on many diesel-electric locomotives.

Auxiliary motors are designed to operate on 600-volt direct current. In the a-c. zone, an auxiliary rectifier supplies this power.

Stereomicroscopes Used on Assembly Lines.—Stereomicroscopes are playing an increasing role in the manufacture and inspection of metal

products, electronic components, and other items that require high precision or purity, according to the Bausch & Lomb Optical Co., Rochester, N. Y., a leading producer of the instruments.

In metal working, food processing, chemical, tobacco, textile, and electronic industries, the instruments detect flaws and impurities, helping workers do high precision work with a minimum of the training previously required. Because stereomicroscopes greatly reduce eye strain, some plants have noted a definite upswing in employee relations when the instruments were adopted.

At the Fairchild Camera & Instrument Corp., Hicksville, L. I., for example, stereomicroscopes are used to permit the operator to assemble accurately potentiometers one half-inch in diameter containing 35 parts. Because the potentiometer is a critical sensing element in the control system of guided missiles, precision manufacture is vital. Stereomicroscopes were largely limited to laboratory use until World War II, when great quantities of precision goods were needed and the pool of skilled labor was small. The instruments permitted workers to perform tasks far beyond their normal training level, breaking many bottlenecks. Demand for 3-D 'scopes has continued to increase ever since. Magnification produced by stereomicroscopes ranges from six to one hundred fifty diameters depending on working requirements.

"Iso-Plus" High-Yield Process for 100-Octane Motor Fuel.—Houdry Process Corporation has announced development of the Houdry Iso-Plus Reforming Process by which high yields of 100-octane clear automobile gasoline may be obtained from low-octane napthas produced in day-to-day refinery operations. Pilot plant runs of the new process in three schematic variations produced approximately 86, 87 and 91 per cent conversion of naphtha feed stock to 100-octane clear gasoline. Addition of tetra-ethyl lead would further increase the octane number.

With slight operational modification, it was said, one of the three Iso-Plus variations would yield more than 82 per cent conversion to 108-octane (F-1 clear) gasoline for blending with refinery pool gasolines of lower anti-knock rating, resulting in higher overall pool octane number.

The new process is named Iso-Plus because the anti-knock rating of its product equals the 100-octane rating of iso-octane (2,2,4-trimethylpentane) used in determining gasoline octane numbers, and because it involves Houdry catalytic reforming plus other processing.

In the light of predictions that 300-horsepower automobile engines may be the rule by 1960, it was pointed out that refiners today find themselves lining up for a "high octane derby."

Increasing quantities of gasoline of ever-mounting octane-number are required so that today's high-rated automobile engines and those still on the motor industry's drafting boards may be operated at top efficiency.

Premium 98-octane fuel is already on the market, and the refining industry is forecasting 100-octane premium fuels in the foreseeable future. The new Houdry process was described as "an economically feasible means" by which the refining industry may increase output of high-octane fuel for modern high-compression automobile engines.

Single-stage Houdriforming units, such as those now in operation at a number of refineries, are capable of converting high proportions of naphtha charge to 100-octane gasoline. The point was made, however, that

this is possible only when operating the Houdriforming reactors at severe intensity with naphthas of low paraffin content as feed stock.

Because of these limitations, methods of using Houdriforming in combination with additional processing were investigated. The new Iso-Plus process, with several optional processing combinations, is the result.

One Iso-Plus route permits the combining of Houdriforming and aromatics extraction in either of two arrangements, and the other variation utilizes Houdriforming in combination with thermal reforming.

Space Satellite May Relay TV Across Ocean.—The possibility of using man-made space satellites as a means of relaying television across the ocean was disclosed by Dr. John R. Pierce, director of electronics research of Bell Telephone Laboratories, at the opening session of the national convention of the Institute of Radio Engineers.

Good reception would be electronically feasible by using a 100-ft. satellite in an orbit 22,000 miles above the earth to reflect television signals from one continent to another. This would require an antenna 250 ft. in diameter at the sending and receiving stations on earth and a transmitter power of only 50,000 watts, an achievable figure. At such time as it becomes possible to construct such a satellite, the chief problem would be keeping the satellite's reflecting surface steadily aimed in the proper direction.

The disclosure came at a symposium on space stations which opened the four-day program of electronic exhibits and technical papers being held by the Institute of Radio Engineers at the Kingsbridge Armory and Waldorf-Astoria Hotel. The convention was attended by some 40,000 engineers and scientists from all parts of the world.

Among other speakers at the symposium was Prof. S. F. Singer, physics department of the University of Maryland, who reported that the technical problems connected with launching, control and instrumentation of a very small man-made satellite called the MOUSE (Minimum Orbital Unmanned Satellite of the Earth) are well within the range of present techniques. Among the many scientific instruments which would be installed in the MOUSE would be one which measures the sunlight reflected by the earth. This would give a measure of the total world cloud coverage which, in turn, could be used to forecast long-range climatic changes.

Microscope Accessory to Identify Minerals.—A microscope accessory to aid in identifying minerals and chemicals has been introduced by the Bausch & Lomb Optical Co., Rochester, N. Y. Known as an accessory slot compensator, it will speed the identification process by geologists and chemists.

The first step in identifying a mineral is to measure "birefringence" with the accessory slot compensator. Determination charts are then used to obtain readings. Determinations correct to plus or minus 2 per cent without calibration are read directly in millimicrons from a scale engraved on a rotatable drum. No computations or conversion tables are needed and training time is substantially reduced.

The instrument performs with greatest efficiency when used with light having a wavelength of 5890 Angstroms. To achieve this light value, an interference filter is available for use with tungsten illuminators.

Retardations from 0 to 2700 millimicrons can be measured simply with the B&L accessory slot compensator. Scale division values engraved on the side of the instrument provide a per-

manent record and a means of quick reference.

Survey of Emergency Lighting Equipment.—The average American is better equipped to cope with a lighting emergency in his home than during a nighttime automobile mishap, according to the first major survey on the nation's emergency lighting equipment. In reporting results of the survey, Rodman St. Clair, general manager of the Electrical Division of Olin Mathieson Chemical Corporation, pointed out that 49.4 per cent of the motoring public carried no electrical emergency lighting equipment in their automobiles. The survey was made in Kansas City, Mo., which was chosen as typical of American urban areas.

Mr. St. Clair reported the survey also found that only 58.7 per cent of the population were confident their flashlights would light. The lack of concern in whether a flashlight might give light during an automobile or home emergency was shown by the fact that 53.4 per cent of those queried hadn't tested their flashlights in a month.

"The study makes it particularly clear that the average motorist is poorly prepared for an emergency," Mr. St. Clair stated. "The kind of accident that occurs because a driver can't see the car owner changing his tire until it is too late is generally the serious type of accident.

"Moreover," he said, "there is the matter of convenience. Flat tires are common enough so that virtually everyone is familiar with such a mishap. Changing a tire on a dark road in the dead of night makes a chore out of what should be a relatively simple task."

He added that the ideal emergency light for an automobile is a flashlight, or lantern, capable of projecting a beam at least 700 feet. If a flashlight is used, it should fit into a glove compartment. If a lantern is used, it should be attached to the cowl under the dashboard. A driver, stalled on a dark road, should not step out of his car without a hand light.

It also is the better part of common sense to keep two extra batteries—or the number required for your emergency light—in the glove compartment of a car. If the emergency light should fail because of worn out batteries, new batteries can be inserted. A battery, not in use, can be stored for 12 months without loss of energy.

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